

DLA ENERGY BIOFUEL FEEDSTOCK METRICS STUDY

REPORT DESI2T1

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DECEMBER 2012

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 11 DEC 2012		2. REPORT TYPE Final		3. DATES COVERED 22-06-2011 to 11-12-2012	
4. TITLE AND SUBTITLE DLA ENERGY BIOFUEL FEEDSTOCK METRICS STUDY			5a. CONTRACT NUMBER SP0600-10-D5012/1003		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Jeremey Alcorn			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Logistics Management Institute, 2000 Corporate Ridge, McLean, VA, 22102-9800			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Deense Logistics Agency, Energy, 8725 John J. Kingman RD, Fort Belvoir, VA, 22060-6222			10. SPONSOR/MONITOR'S ACRONYM(S) DLA Energy		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Results and assessment framework developed by LMI in the performance of a DLA Energy commissioned study to: establish a foundation for the ongoing assessment of emerging feedstocks and biofuel pathways; meet future military service demand for next-generation, drop-in operational biofuels; and contribute to the achievement of national security, energy, environmental, and mission sustainability goals.					
15. SUBJECT TERMS alternative fuel, biofuel, sustainability, framework					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT 1	18. NUMBER OF PAGES 370	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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DLA Energy Biofuel Feedstock Metrics Study

DES12T1/DECEMBER 2012

Executive Summary

Defense Logistics Agency (DLA) Energy is the executive agent for bulk petroleum fuels for the Department of Defense (DoD) and military services. DLA Energy procures drop-in operational biofuels, ensuring an ample supply to meet anticipated demand and fulfill warfighter requirements. DLA Energy commissioned this study to

- ◆ establish a foundation for the ongoing assessment of emerging feedstocks and biofuel pathways,
- ◆ meet future military service demand for next-generation, drop-in operational biofuels, and
- ◆ contribute to the achievement of national security, energy, environmental, and mission sustainability goals.

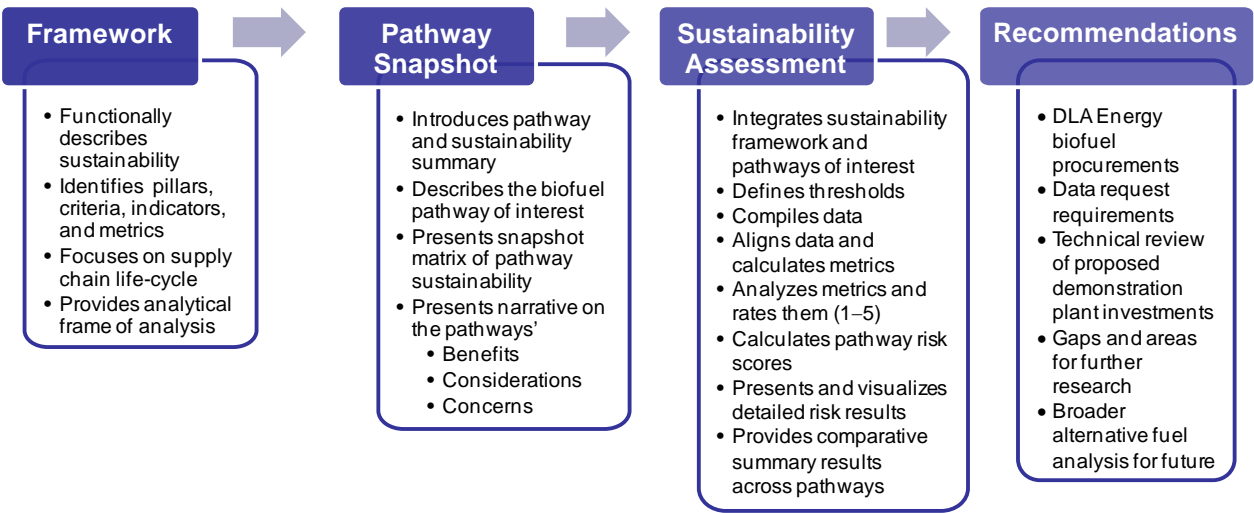
DLA Energy sought to achieve greater awareness and understanding of operational biofuel sustainable supply chain criteria. Drop-in biofuel feedstocks and production pathways present a variety of novel upstream sustainability benefits, considerations and concerns not considered when procuring traditional petroleum-based bulk fuels. As the military services' demand for these operational biofuels grows, DLA Energy increasingly requires a sustainability architecture to consistently identify and evaluate these operational fuels' supply chain risks. We developed this architecture to serve key DLA Energy roles and business line needs for

- ◆ operational biofuel procurement criteria for best-value tradeoff evaluations;
- ◆ due diligence technical reviews of regional demonstrations and production facility proposals; and
- ◆ needs identification for its research and development (R&D) program investments and partnerships.

In collaboration with DLA Energy, we developed a biofuel sustainability architecture (Figure ES-1) that consistently frames sustainability, describes the biofuel

life-cycle, assesses supply chain risks, and informs analysis and decisions. The sustainability assessment component evaluates the supply chain risks of a particular biofuel, comparatively analyzing numerous pathways risks.

Figure ES-1. Proposed Biofuel Sustainability Architecture



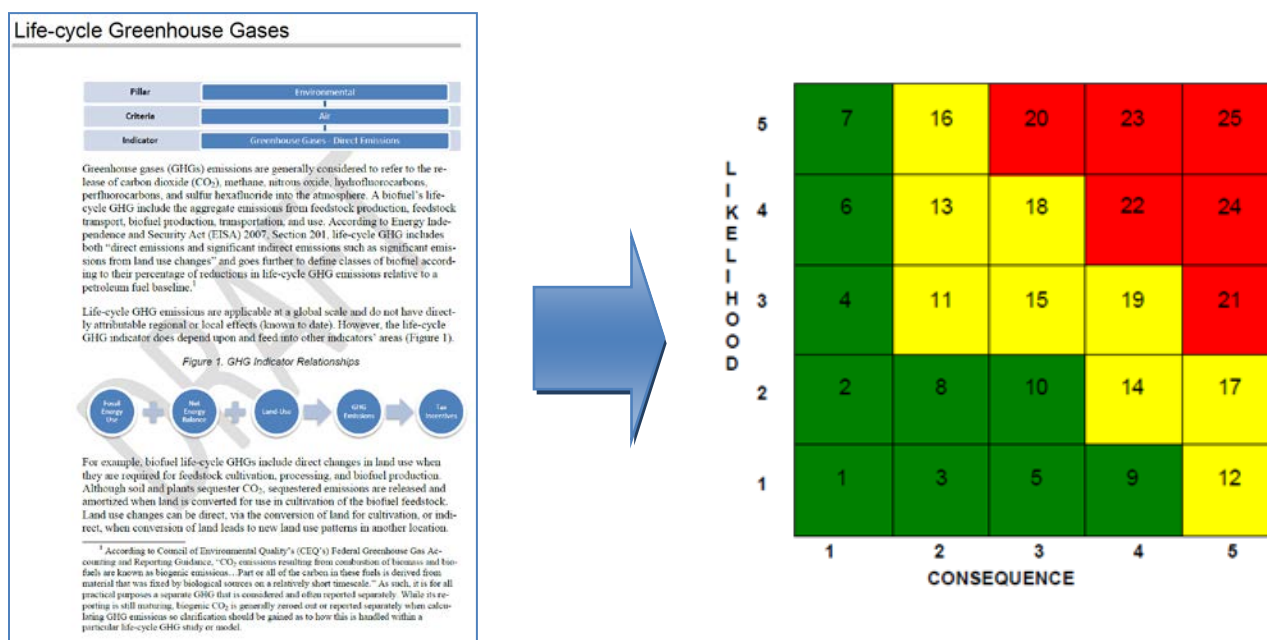
We selected criteria and indicators that reflect laws, regulations, and policy; the technical rigor of subject matter expert frameworks; and consensus-based sustainability standards. We integrated these criteria and indicators to create a relevant, consistent, and widely applicable biofuel sustainability framework (Figure ES-2).

Figure ES-2. Proposed Biofuel Sustainability Framework



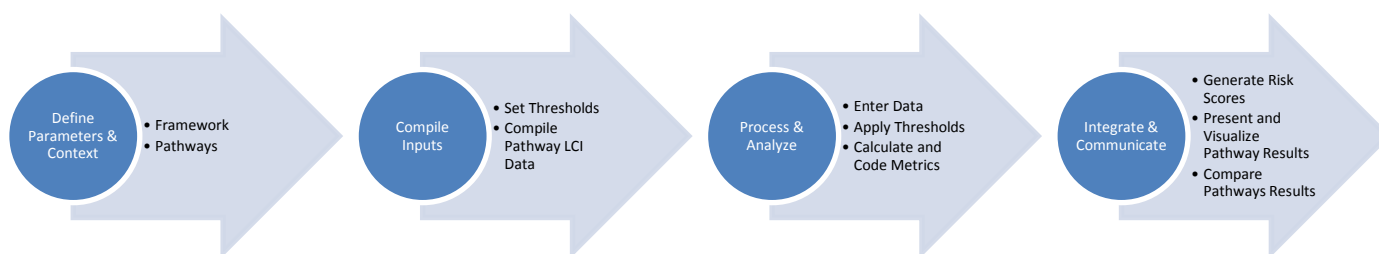
Using this framework, we developed indicator technical sheets with several metrics that robustly frame, assess, and manage issues of concern throughout the bio-fuel life-cycle. Each indicator technical sheet, its identified metrics, and analysis thresholds further operationalize the indicators by applying the concepts of likelihood (degree of supply chain hazard), feedstock and conversion pathway characteristics, consequence (severity of supply chain impacts), regional or local conditions or relative sensitivities, and mitigation (of the supply chain risk) plans, technologies, or practices to manage or reduce the raw risk (Figure ES-3).

Figure ES-3. Indicator Technical Sheet to 5 × 5 Risk Matrix



The DoD acquisition community already widely employs risk management (see MIL-STD-882E). Applying sustainable supply chain risk management will facilitate clearer communication within DLA Energy's business processes, across the DLA enterprise, and with military service clients, the Office of the Secretary of Defense, and interagency collaborators, including the Federal Aviation Administration and Departments of Energy and Agriculture. We propose this approach so DLA Energy can consistently apply these sustainability indicators and metrics to biofuel pathways and robustly assess their sustainability (Figure ES-4).

Figure ES-4. Sustainability Assessment Process



DLA Energy will not, however, realize the proposed architecture's full value in decision making absent its integration with DLA business processes. To do so, we propose adopting a continuous risk management (CRM)-based approach already used in other DLA and federal supply chain and sustainability programs. This approach can build on best practices for supply chain management, such as the Supply Chain Operations Reference (SCOR) model and GreenSCOR, particularly given their compatibility with life-cycle analysis.

The results and recommendations will be specific, measurable, attainable, relevant, and timely. Moreover, the CRM paradigm and risk language will make the process transparent and outcomes defensible should procurements or technical reviews require external review or audit. Finally, the maintenance of this sustainability architecture will require both internal DLA Energy collaboration and ongoing partnerships with other federal agencies, which will offer an entrée for discussing and driving the interagency research and analysis priorities.

In the near term, it is premature for DLA Energy to accept or adopt any particular biofuel standard or certification. We propose integrating the sustainability architecture and assessment process into DLA Energy business processes. It should be used as an internal government sustainability assessment that can first demonstrate Section 526 compliance and second consistently incorporate the military services' desired criteria (energy, water, and food security) into DLA Energy decisions.

We recommend the following moving forward:

- ◆ Adopt the proposed sustainability architecture.
- ◆ Integrate it with DLA Energy business processes.
- ◆ Engage internal stakeholders to vet it and external partners to cultivate support and ownership.
- ◆ Coordinate its maturation and use with interagency partners and DLA policy, strategies, and initiatives.

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Chapter 1

Introduction

The Defense Logistics Agency (DLA) Energy mission is to “provide the Department of Defense [DoD] and other government agencies with comprehensive energy solutions in the most effective and efficient manner possible.”¹ As a customer-oriented organization, DLA Energy is driven by warfighter needs and strives to do what is right for the military services and DoD.² In recent years, DoD and the services have developed aggressive energy security strategies, goals, plans, and initiatives, particularly in the alternative fuel, renewable fuel, and biofuel arena. These efforts are spurring considerable demand for next-generation biofuels to meet their energy security, environmental, and mission sustainability aims. For its military service customers to meet their leading-edge goals, DLA Energy’s unique technical expertise and role in identifying, reviewing, and procuring the next-generation operational biofuels is critical.

However, next-generation biofuels have implications beyond procuring sufficient quantities and assuring the delivery of on-spec fuel. They entail novel production, sustainment, and environment-related risks that span the supply chain—from feedstock cultivation, to biofuel production, to end use by the warfighter. While the risks are not insurmountable, DLA Energy required additional expertise and partners, a biofuel supply chain risk management approach, and meaningful sustainability assessment metrics to support its procurement roles. To this end, DLA Energy asked LMI to develop measurable biofuel sustainability metrics—that apply throughout the fuel life-cycle—relevant to its research and development (R&D), technical review, and procurement roles.

PURPOSE AND OBJECTIVES

DLA Energy is the executive agent responsible for bulk petroleum fuels, making it the purchaser of the advanced biofuels necessary to meet the anticipated demand of the military services and fulfill warfighter requirements. This study supports DLA Energy aims to

- ◆ establish a foundation for the ongoing assessment of emerging feedstocks and fuel pathways;
- ◆ meet future military service demand for next-generation, drop-in operational biofuels; and

¹ DLA, *Defense Logistics Agency Energy 2011 Commander’s Guidance*, (2011).

² DLA, *Defense Logistics Agency Energy Fiscal 2012 Annual Operating Plan*, (2011), DLA%20Energy%20Annual%20Operating%20Plan-AP[1].pdf.

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- ◆ attain national security, environmental, and mission sustainability goals.

DLA Energy required a fuller awareness of the sustainability criteria of these emerging alternative operational fuels. Biofuel feedstocks and their production pathways present a variety of upstream sustainability opportunities, considerations, and uncertainties not considered when procuring traditional petroleum-based, commodity fuels. As the demand for new biofuels grows and DoD engages the maturing market, DLA Energy requires new knowledge, a framework, and a tailored biofuel sustainability architecture to evaluate the relative biofuel benefits, concerns, and tradeoffs to inform program, due diligence technical review, and procurement decisions. This study fulfills these needs.

This study aims to

- ◆ improve awareness of relevant sustainability components, particularly specific environmental benefits, concerns, and gaps associated with feedstocks and their respective conversion pathways;
- ◆ map the data, analysis approaches, and tools to quantify and assess biofuel supply chain sustainability risks;
- ◆ identify data gaps and partners with which to address them; and
- ◆ recommend an architecture,³ framework,⁴ approaches, and metric options to help DLA Energy identify, assess, and manage the tradeoffs associated with different biofuel products.

We sought to develop an integrative sustainability framework comprising pillars,⁵ criteria,⁶ and indicators,⁷ as well as a DLA Energy-tailored biofuel sustainability architecture. Sustainability is not a new concept, but the marriage of federal sustainability mandates, energy security, and the advanced biofuel supply chain require careful consideration of these unique, yet increasingly interrelated contexts.

³ *Architecture* refers to the functional components needed to frame the sustainability analysis, identify biofuel pathway of interest, process for performing an assessment, and outputs that inform insights, recommendations, and decisions.

⁴ *Framework* refers to a basic conceptual structure and hierarchy that can be used to consistently assess the individual or relative sustainability of a given biofuel.

⁵ *Pillars* refer to the foundational principles and groupings within a given sustainability framework that may include economic, operational, environmental, and social aspects. Each pillar is composed of one or more criteria.

⁶ *Criteria* refer to secondary categories within a specific pillar that describe resources, media, capacities, or other attributes across the biofuel life-cycle. Criteria are composed of one or more indicators.

⁷ *Indicators* refer to specific gauges of performance, impact, and supply chain risk for a given criterion. One or more quantitatively or qualitatively defined metrics may be used to assign values.

DoD AND SERVICE BIOFUEL REQUIREMENTS

The 2010 Quadrennial Defense Review (QDR) recognizes a strategic imperative to consider energy security and climate change because of their potential effect on national security and mission readiness.⁸ For DoD, energy security means having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs.⁹ Our military services' reliance on finite, petroleum-based fossil fuels poses a strategic and real threat to the accomplishment of their core missions. Tightening global petroleum supplies and unstable regimes in some oil-producing nations contribute to price volatility, raising energy costs, and making already tough budget decisions untenable. The growing global demand for energy is outstripping projected petroleum production and refining capacity,¹⁰ exacerbating these challenges.

With an FY11 energy bill of \$20 billion, DoD is one of the largest energy consumers in the United States and the biggest in the federal government.¹¹ Almost every US military capability and mission achievement rest upon a reliable supply of operational fuel, which is currently petroleum based.¹² Energy security is not a hypothetical problem for the military services given the growing budgeting challenges posed by increased price volatility in fuel contracts over the past several years. For example, the Navy alone experienced a jump in its annual fuel costs from \$1.2 billion to \$5 billion in just a year (FY08).¹³ In her testimony to Congress, Sharon Burke, Assistant Secretary of Defense for Operational Energy Plans and Programs, ASD (OEPP), noted, "unpredictable fuel bills ... crowd out other investment [and] every dollar hike in the price of oil per barrel raises our [DoD's fuel] bill by \$130 million."¹⁴ These steadily rising and volatile petroleum-based mobility fuel costs have an adverse effect on military service programs and capabilities, particularly when combined with a tough appropriations environment.

Recognizing these mission readiness risks, the military services have all developed energy security strategies and plans, which include a component on diversifying energy sources and emphasis on enabling the future use of alternative operational fuels. These have included or been accompanied by quantitative alternative fuel goals, which send industry a notable demand signal. A July 2011 DoD report, *Opportunities for DoD Use of Alternative and Renewable Fuels*, cites

⁸ DoD, *Strategic Sustainability Performance Plan, FY2010*, August 26, 2010.

⁹ US Secretary of Defense, *Quadrennial Defense Review Report*, (Washington, DC: February 2010), http://www.defense.gov/qdr/images/QDR_as_of_12Feb10_1000.pdf.

¹⁰ See footnote 8, this chapter.

¹¹ Sharon Burke, Assistant Secretary of Defense for Operational Energy Plans and Programs, testimony to Subcommittee on Readiness, House Armed Services Committee, United States House of Representatives, March 29, 2012, armedservices.house.gov/index.cfm/files/serve?File_id=bf6fdb00-0e8c-467a-a275-69b62940ae48.

¹² Ibid.

¹³ Alaina Chambers and Steve Yetiv, "The Great Green Fleet, The US Navy and Fossil Fuel Alternatives," *Naval War College Review*, Vol. 64, No. 3 (Summer 2011), p. 66.

¹⁴ See footnote 11, this chapter.

these quantities, and this study revisits and updates them. Although these fuels are often called “alternative,” DoD’s compliance with life-cycle greenhouse gas (GHG) limits—specifically Section 526 of the Energy Security and Independence Act of 2007 (EISA)—effectively means next-generation, drop-in biofuels, such as hydroprocessed esters and fatty acids (HEFA) and bio-derived synthetic paraffinic kerosene (bio-SPK).

SUSTAINABILITY AND ITS RELEVANCE

What is sustainability? Over the last quarter century, many organizations and federal departments started the process of grappling with this seemingly simple yet vexing question. In doing so, they have started reevaluating their mission, operations, and culture to ensure they remain relevant, capable, and viable into the future using the “triple bottom line” (economic, environmental, and social) paradigm. The military services have been leaders in advancing sustainability since the early 2000s and began to integrate its tenets into their respective ethos, operations, plans, and policies, particularly within the installation and base communities (from the bottom up).

In recent years, Executive Orders (EOs) 13423 and 13514 mandated the incorporation of mission sustainability in departmental leadership, policies, and metrics.¹⁵ In these EOs,

“sustainability” and “sustainable” mean to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations.¹⁶

EO 13514 goes on to mandate the establishment of senior sustainability officers (SSOs), departmental strategic sustainability performance plans (SSPPs), and Office of Management and Budget (OMB) sustainability scorecard metrics.¹⁷

As a result, DoD developed FY10 and FY11 SSPPs that lays out its vision, goals, and performance expectations into future years.¹⁸ The FY11 SSPP asserts DoD’s commitment to not only “complying with environmental and energy statutes, reg-

¹⁵ More background on federal sustainability is available at: Federal Facilities Environmental Stewardship & Compliance Assistance Center, “Sustainability,” *FedCenter*, www.fedcenter.gov/programs/sustainability/.

¹⁶ US Federal Register, *Federal Leadership in Environmental, Energy, and Economic Performance*, EO 13514, October 5, 2009, www.fedcenter.gov/_kd/go.cfm?destination=ShowItem&Item_ID=13641.

¹⁷ Executive Office of the President, *Sustainability: Leading by Example in Environmental, Energy, and Economic Performance*, www.sustainability.performance.gov/.

¹⁸ See footnote 8, this chapter.

ulations, and Executive Orders, but to going beyond compliance where it serves our national security needs.”¹⁹ The SSPP states it is

DoD policy to address sustainability concepts in our acquisition and procurement processes, and in planning and managing our installations. We are committed to integrated risk management practices that protect the environment and promote sustainability while advancing our mission.²⁰

The military service sustainability strategies, goals, and efforts build on this policy, and they incorporate sustainability into their operations and procurements. Energy security is often cited as a key priority and component.

Herein lays the core relevance and intersection between biofuels and sustainability. Operational biofuels represent an opportunity and means for improving military service and DoD mission sustainability. Properly pursued, they address a pressing national security imperative and support truly enduring mission accomplishment. However, sustainable mission readiness requires DLA Energy’s technical leadership and enhanced capabilities to meet these new warfighter requirements. DLA Energy must procure sufficient quantities of these newly developed fuels *and* assess their life-cycle sustainability tradeoffs.

DLA ENERGY ROLES AND METRICS

As the bulk fuels executive agent, DLA Energy’s role in DoD biofuel use (sustainability metrics, framework, assessment process, and architecture) would seem to be limited to informing future procurements. (As noted in the performance work statement, this end-use application is an important focus of this study.) However, DLA Energy identified and expanded the realm of likely applications on the basis of its current support roles and responsibilities. From these new needs, we identified the following application of biofuels sustainability metrics:

- ◆ Best-value tradeoff evaluation approach for biofuel procurements
- ◆ Due diligence technical reviews of regional operational demonstrations and production facility proposals
- ◆ Needs identification to inform R&D program investments and partnerships.

Evaluation of Biofuel Procurements

DLA Energy is the executive agent for class III bulk fuel procurement and meets the requirements set by the military service control points. Conventional fuel purchases have traditionally been its primary responsibility, but DLA Energy has

¹⁹ Ibid.

²⁰ Ibid.

become the focal point for the growing number of drop-in alternative and biofuel procurements in recent years. Most of these advanced biofuel procurements have been small quantities to support fuel research, development, demonstration, qualification testing, and weapon platform certification efforts. However, recent procurements, such as the Navy purchase of 450,000 gallons for the “Green Fleet Demo,” and future commercial-scale procurements require sustainability due diligence (for life-cycle GHG, water, and non-food) and draw much wider scrutiny to demonstrate statutory compliance (with EISA Section 526, for example).

Conventional fuel purchases have been the lowest-cost, technically acceptable (meets specification) procurements, but the paradigm for biofuels may require a best-value tradeoff approach. However, if best-value tradeoff is appropriate, the criteria and selection process now require a complementary sustainability review and metrics to easily inform source selection board evaluations and decisions. A possible analog is the independent government cost estimate (IGCE), which independently estimates costs for comparison of vendor proposals; sustainability would call for an independent government sustainability assessment (IGSA). While the assessment of sustainability may provide a quantitative comparison of some attributes, it will also certainly identify uncertainties associated with specific aspects of newly qualified, drop-in biofuels. Better DLA Energy understanding of these uncertainties can likewise influence solicitation requirements and may direct or influence new research and information collection activities associated with biofuels.

Due Diligence Technical Review

DLA Energy and its quality technical (QT) team are increasingly relied upon for their leadership, fuels expertise, and technical input for the military services’ biofuel operational demonstration efforts and interagency Defense Production Act (DPA) activities. Their core competencies in fuel logistics and quality assurance are, out of necessity, growing to include the upstream supply chain activities from the biorefinery, processing, transportation, and feedstock production. Given the new technical risk inherent in operational demonstrations and government investment in commercial-scale biorefineries, DLA Energy’s QT team rapidly requires capabilities to help provide awareness of regional or site-specific sustainability attributes and supply chain risks. This study and its proposed sustainability architecture provide the framework and assessment approach to identify hazards, risks, and mitigations when reviewing biofuel production proposals.

Needs Identification

DLA Energy’s R&D program has provided technical leadership in advanced biofuels research for DoD and its interagency collaboration and has catalyzed the exploration of pressing energy logistics and technology challenges. While supporting the aforementioned DLA Energy mission roles, the biofuel

sustainability architecture will also provide an opportunity to identify gaps and work through high-priority criteria, indicators, and metrics. The data availability and technical feasibility of some indicators quickly become evident when they are used as part of the sustainability architecture. For instance, early in this study, we noted the lack of research, data, and tools addressing marine diesel fuel, but this finding has now led to interagency work plans aimed to address this gap, so future data, analysis, and tools will include results for this key operational fuel product. Likewise, the gaps identified while developing sustainability criteria, indicators, metrics, and pathway assessments can be considered in future year R&D work plans or addressed through collaboration with other agencies and partners.

STUDY SCOPE

To accomplish our aims, DLA Energy and LMI carefully defined the preliminary study scope. Three areas required careful consideration early on and throughout this effort. The study team sought to identify the desired areas of emphasis, consistently define life-cycle stages and align analysis boundaries, and choose representative fuel pathways for deeper analysis.

Broad Sustainability, But Environmental Pillar Focus

This project's original charge was to develop metrics that cover economic viability; GHG and other emissions; water, land, and environmental impacts; and overarching sustainability. On the basis of DLA Energy direction (to research and develop sustainability metrics for evaluating domestic, next-generation biofuel feedstocks), the study initially considered a broad suite of sustainability pillars (operational, economic, environmental, and social) but focused on environmental sustainability indicators. This prioritization reflected concurrent work on and decisions concerning the broader sustainability of biofuels and their feedstocks, encompassing a wider group of operational, economic, and social factors, which other DLA Energy efforts were already addressing, such those of ASTM International working groups and DLA Office of Operations Research and Resource Analysis (DORRA). Thus, we strove to collect, incorporate, and integrate information from these complementary efforts in developing a comprehensive, sustainability architecture. However, our research and partnering efforts focused on addressing the limited awareness and acute data gaps, particularly under the environmental pillar.

Biofuel Life-Cycle Stages

We initially focused on feedstock production and conversion (cultivation, pre-processing, and development of intermediate products). However, early research suggested this narrow perspective would impede the understanding of differing system boundaries and represent a barrier in linking these analyses to gallons of fuel procured. Our initial research quickly indicated a need to consider the full fuel life-cycle, establishing default boundaries, and clearly defining discrete

life-cycle stages, such as feedstock production (preparing fields and planting, growing, and harvesting), transportation (collecting feedstock and preprocessing), feedstock conversion and fuel production (conversion processing, refining, and blending), fuel distribution, and fuel use.

For consistency, we sought to conform with the International Organization for Standardization (ISO) 14040:2006E and 14040:2006E standards and leverage the work of the interagency Aviation Fuel Life-Cycle Analysis Working Group, including the *Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels*.²¹ We identified approaches, data, and analysis and sought to align them with the following six general life-cycle stages:

- ◆ Stage 1—Raw material acquisition
- ◆ Stage 2—Raw material preprocessing and transport
- ◆ Stage 3—Liquid fuels production
- ◆ Stage 4—Product transport and refueling
- ◆ Stage 5—Use (aircraft operation)
- ◆ Stage 6—End of life.

Stages 1–5 apply and are calculated throughout the biofuel life-cycle, but stage 6 does not apply as the fuel is consumed in stage 5. This life-cycle construct is often referred to as well-to-wheels and well-to-wake. These stages are the preferred boundaries for organizing data and analysis to ensure consistency and comparability. However, we found variations in life-cycle boundaries, co-product allocation methods, and assumptions, which often explain some differences in analysis results.

In addition to scope, there are several levels²² of life-cycle analysis (LCA) resolution and their use should be determined by the intended end use, such as generating research and development (R&D) inputs (Level III), screening Service-sponsored operational demonstrations (Level III and II), or evaluating specific biofuels procurements (Level II and I) for compliance with EISA, Section 526 and Environmental Protection Agency (EPA) renewable fuel standard (RFS) 2 biofuel category qualification. Taken together, these findings reinforces the need to seek transparent data, document the boundaries and assumptions applied, and

²¹ Aviation Fuel Life-Cycle Analysis Working Group, *Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels*, AFRL-RZ-Wp-TR-2009-2206 (Air Force Research Laboratory, Wright Patterson Air Force Base, OH: 2009), www.netl.doe.gov/energyanalyses/pubs/EstGHGFtrntsAvFuels2009.pdf.

²² There are generally three levels of LCA's that include: Level I: Comprehensive, Level II: Standard, and Level III: Screening. These vary in the process fidelity and data detail and serve different end uses given the level of accuracy reflected in the results. More information is available at: www.netl.doe.gov/energyanalyses/pubs/EstGHGFtrntsAvFuels2009.pdf.

align the system boundaries to the extent possible when selecting inputs and using them to assess biofuel sustainability.

Biofuel Pathways of Interest

During the study, the landscape of possible biofuel feedstocks and conversion pathways rapidly expanded. Virtually any product of net primary production (NPP) that generates extractable sugars, ligno-cellulose, or oils/lipids can technically be made into a synthetic biocrude that replaces the need for petroleum. In our early research, we sought to identify, capture, and organize possible feedstocks, conversion processes, and synthetic fuels from the literature. This initial analysis captured a broad universe of feedstocks (algal, food and energy crops, forest products, co-products and residues, and wastes), developed consistent categories, and subsequently mapped them to known conversion technologies, both established, including Fischer-Tropsch (F-T) and hydrotreatment, and emergent, such as alcohol oligomerization, catalytic, and microbial conversion.

As in considering sustainability, we cast a broad net but focused our deeper analysis on particularly timely examples. Given the DLA Energy roles and intended application of this research, the feedstock to be evaluated depended on the type (for example, comparative evaluation of wastes, food crops, and energy crops) and availability of data. In addition, the initial conversion pathways considered need to be capable of producing drop-in biofuels already qualified for use in tactical systems and in certified weapons platforms (F-T and HEFA). Considering these factors, we examined HEFA jet fuel blend stock generated from waste vegetable oils and animal fats, virgin soybean oils, and camelina oil.

REPORT ORGANIZATION

This report has two complementary purposes. First, it documents the research approach, analysis, and findings of this study. Second, it furnishes a baseline understanding of the nexus between advanced biofuels and sustainability while proposing an architecture with which to operationalize supply chain risk management of these new fuel products. The remainder is organized as follows:

- ◆ Chapter 2 is an overview of the study approach, research, collaborator identification and outreach, sustainability framework integration, and biofuel sustainability architecture development processes.
- ◆ Chapter 3 introduces the key concepts and our analysis of the implications of key statutes, regulations, and policies by sustainability pillar and criteria areas.
- ◆ Chapter 4 describes the resultant federal agency bioenergy roles, their programs, and relevant biofuel public-private sustainability efforts.

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- ◆ Chapter 5 continues this exploration of federal sustainability, energy security, and drop-in biofuels in the context of DoD, applicable defense agencies, and military services.
 - ◆ Chapter 6 proposes the DLA Energy biofuel sustainability architecture, introduces its progression and components, and elaborates the component sustainability framework, pathway snapshots, assessment, and outcomes.
 - ◆ Chapter 7 presents our conclusions and recommendations.

Chapter 2

Study Approach

DLA Energy launched this study to develop metrics to inform its decisions on drop-in biofuel policies, initiatives, and procurement strategies. The study approach consisted of five key activities:

- ◆ Researching, reviewing, and synthesizing literature
- ◆ Reaching out to stakeholders and collaborators
- ◆ Analyzing US government and DoD requirements
- ◆ Developing a biofuel sustainability framework and indicators
- ◆ Preparing recommendations for assessing the sustainability of biofuels.

In this chapter, we describe our approach and detail each of these efforts.

LITERATURE REVIEW AND SYNTHESIS

We searched bibliographies for biofuel-related studies, particularly those with biofuel feedstock and sustainability-related metrics, indicators, and decision support tools. The literature included DoD-specific resources, studies by or for other federal government entities, relevant academic or industry publications, and relevant international publications.

LMI's research librarians targeted several bibliographic databases, including Scopus.com (from Elsevier Publishing), the Department of Energy (DOE) Information Bridge,¹ and Energy Technology Data Exchange's World Energy Base (ETDEWEB).² They searched title, abstract, and keyword fields to identify recent (post-1994) resources using various key word combinations (such as bioenergy, biofuel, biodiesel, biomass, feedstock, metric, assessment, certification, indicator, measure, sustainability, environment, effects, impacts, green, and ecological). Our analysts reviewed the relevant resources and captured information for pertinent resources—citation (title, corporate authors, personal authors, publication date, and publication number), citation source, website, abstract, task relevance (feedstock/source, intermediate product, process, fuel type, and criteria area) key findings, and outcomes—in a Microsoft Excel-based resource catalog.

¹ US DOE, Office of Science, *Information Bridge*, www.osti.gov/bridge/advancedsearch.jsp.

² Energy Technology Network, *ETDEWEB*, www.etde.org/etdeweb/basicsearch.jsp?pg=2.

When possible, we downloaded full-text copies of the resources. When full-text articles were unavailable, we downloaded abstracts and links. We also leveraged previously identified applicable references and captured their bibliographic information in the resource catalog, which, by the end of the study, contained more than 400 resources.

In addition to the bibliographical search, we accessed online data and materials from government alternative fuel efforts—such as those of DoD, DOE, the Department of Transportation (DOT), EPA, and the US Department of Agriculture (USDA)—and efforts to study biofuel feedstocks and sustainability, including those of Oak Ridge National Laboratory (ORNL) and the Center for Bioenergy Sustainability.

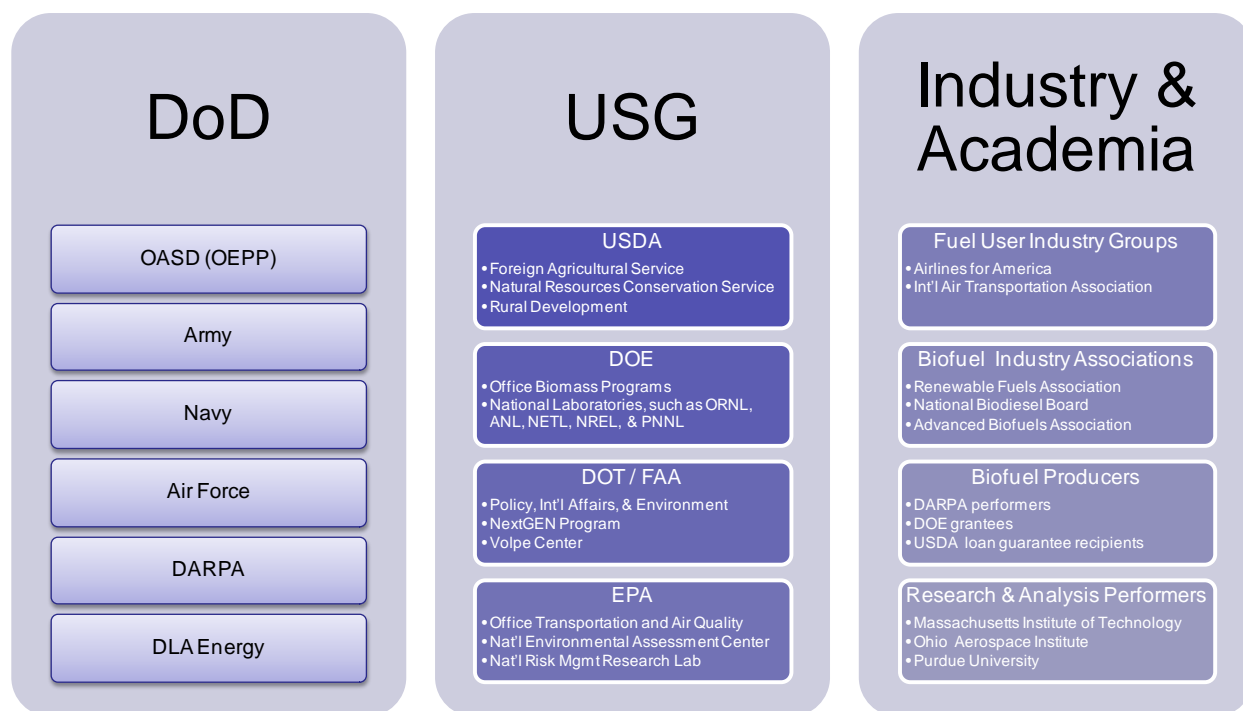
We also collected and analyzed relevant information from academia and trade and industry groups, such as the Commercial Aviation Alternative Fuels Initiative (CAAFI) Environmental Work Group, National Biodiesel Board, and Renewable Fuel Association. We researched international organizations, such as the Food and Agriculture Organization of the United Nations and European Commission, to leverage available information. Although most of our research efforts took place at task onset, follow-on activities spanned the effort as we identified new contacts and information.

OUTREACH AND COLLABORATION

A key element of this study involved collaboration with biofuel stakeholders and relevant subject matter experts (SMEs), particularly those affiliated with US government agencies, programs, and working groups. DLA Energy emphasized the opportunity and need to leverage the expertise of these organizations and experts, and the information gathered to date, to ensure consideration and application of the latest information and concepts.

We worked closely with DLA Energy and other federal-sector biofuel stakeholders to leverage completed and ongoing efforts, reduce duplication of efforts, and cultivate these technical resources as a foundation for advancement. Information generated through these efforts included the descriptions of agencies, programs, initiatives, and their applicable areas of research. Figure 2–1 highlights the contacts that helped cultivate partnerships to share data, analysis, models, tools, research, technical reports, and studies. This collaboration furthered the use of consistent metrics with other federal agencies and helped to establish effective working relationships moving forward.

Figure 2-1. Biofuels and Sustainability Stakeholder Map



Note: OASD (OEPP) = Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs; DARPA = Defense Advanced Research Projects Agency; ANL = Argonne National Laboratory; NETL = National Energy Technology Laboratory; NREL = National Renewable Energy Laboratory; PNNL = Pacific Northwest National Laboratory; FAA = Federal Aviation Administration; IAWG = Interagency Working Group; MOU = memorandum of understanding; BRDI = Biomass Research and Development Initiative; and A4A = Airlines for America.

During the study, we identified relevant individuals and organizations from published literature, organization websites, work group contact lists, and referrals. We contacted and met with federal and industry organizations to introduce the DLA Energy effort, present the approach and objectives, solicit input and collaboration, and establish ongoing dialogues. These discussions facilitated the exchange of data and information, identified additional technical and staff resources, and provided new linkages for feedback on draft work products. Table 2-1 summarizes the organizations contacted during the study.

Table 2-1. List of Organizations Contacted

Type of organization	Organization	Office/sub-organization
US Government (civilian)	USDA	National Institute of Food and Agriculture (NIFA)
		Office of the Secretary & Rural Development
		Office of the USDA Chief Scientist
		Foreign Agricultural Service (FAS)
	DOT	FAA
		Volpe Center
	DOE	ORNL
		NETL
		ANL
		PNNL
		NREL
		Biomass Program
	EPA	Office of Research and Development (ORD) - EPA Headquarters
		ORD - National Risk Management Research Laboratory (NRML)
		ORD - National Center for Environmental Assessment (NCEA)
		Office of Transportation and Air Quality (OTAQ) - Transportation & Climate Division
U.S. Government (defense)	U.S. Air Force	Air Force Center for Engineering and Environment
	DARPA	
	U.S. Army	Army Research Office (ARO)
	Office of the Secretary of Defense (OSD)	
	Office of the Under Secretary of Defense (Acquisition, Logistics, and Technology)–OSD (AT&L)	
Academia	Massachusetts Institute of Technology (MIT)	
	University of Pennsylvania	
Nonprofit	Natural Resources Defense Council (NRDC)	
	National Wildlife Federation (NWF)	

Table 2-1. List of Organizations Contacted

Type of organization	Organization	Office/sub-organization
Industry	A4A	
	Honeywell, UOP	
	LanzaTech	
	General Atomics	
	Logos Technologies, Inc.	
	Virent	
Other	CAAFI	
	Roundtable on Sustainable Biofuels (RSB)	

GOVERNMENT DRIVERS AND DoD REQUIREMENTS

LMI previously studied energy security, alternative fuel, and biofuel statutes, regulations, EOs, rulings, and DoD and military service mandates, most recently in the Section 334 report prepared for DLA Energy and ASD (OEPP). This study sought to update our research on federal statutes and other policy concerning biofuels and broaden its scope to capture sustainability foci and mandates. In addition, DoD has a new operational energy strategy and sustainability plans, and the military service alternative fuel goals and initiatives have evolved. Our team utilized a three-pronged effort to research sustainability, compile the federal statutes and regulation, government policy; monitor OSD policy and strategies; and update military service biofuel-related plans, goals and initiatives' progress.

First, we broadened the research scope and reviewed federal statutes, regulations, and policy on biofuels, environment, and sustainability. We used DLA Energy's preliminary sustainability criteria/topic areas as a starting construct to framework, capture, and reference the relevant drivers and their implications. Concurrently, we identified, reviewed, captured, and mapped DoD and military service sustainability and energy security policies, strategies, and plans using the same criteria and indicator crosswalk matrix.

After delivering this first crosswalk matrix to DLA Energy in December 2011, we continued our research and ongoing monitoring of pending congressional and executive agency actions that could have implications for feedstocks, advanced biofuels, and sustainability requirements via tax incentives, regulatory restrictions, and production mandates. We also continued monitoring OSD, defense agency, and military services' releases of policy, strategy, plans, goals, and initiatives relevant to energy security, alternative fuels, and sustainability. We analyzed the updates and incorporated them in the criteria and indicator crosswalk.

These two efforts utilized publicly available resources, and we also diligently reached out to and engaged OSD, defense agency, and military service stakeholders to ground truth the analysis of strategies, plans, and goals. We captured the latest developments that would influence future demand for biofuels and DLA Energy procurement strategies.

Third, as part of the report preparation process, we reached out to the service control points, in coordination with DLA Energy, to confirm current alternative fuel goals, demand estimates, and biofuel quantity requirements.

BIOFUEL SUSTAINABILITY FRAMEWORK DEVELOPMENT

This study's statement of work listed initial sustainability criteria:

- ◆ Economic viability
- ◆ GHG and air emissions
- ◆ Land
- ◆ Water
- ◆ Other environmental impacts.

Yet, the concept of sustainability as applied to biofuels was not fully or consistently defined. Thus, we sought to develop an initial sustainability framework for DLA Energy and evolve it to maximize statutory and policy relevance, consistency with DoD and military service understanding, and standardization with emerging federal frameworks and industry sustainability standards. In short, we formed an appropriate analytical lens and perspective with which to proceed.

Preliminary Sustainability Framework

The study team held its first meeting in August 2011 to discuss the preliminary study scope, a proposed working sustainability framework, and the DLA Energy desired areas of emphasis within this framework. From the direction received, we focused initial efforts (to research and develop metrics for evaluating domestic, next-generation biofuel feedstocks) on the environmental sustainability pillar. With this initial focus, our working biofuel sustainability framework explicitly acknowledged that decisions concerning the broader sustainability of biofuels and their feedstocks encompass a wider group of operational, economic, and social pillars. However, the DLA Energy team suggested that some of these pillars were already being addressed by other DLA Energy-sponsored efforts, such as those of ASTM International working groups and the DORRA study, which were already addressing some of these pillars. We strove to collect, incorporate, and integrate information from these complementary efforts but initially focused on addressing

the understanding and quantification gaps under the environmental sustainability pillar.

Framework Development Approaches

Building on the literature review, we identified two general methods for developing the sustainability framework, criteria, and indicators. First, in past sustainability assessment efforts, federal agencies identified and selected indicators through crosscutting statutory, regulatory, and policy analysis to determine priorities. They identified indicators by their relevance in a particular context (such as agencies, installations, and biofuels) and chose metrics on the basis of technical feasibility. Second, federal agencies, industry groups, and international organizations have already developed both SME- and consensus-driven biofuel sustainability evaluation frameworks, such as the Global Bioenergy Partnership (GBEP), standards, such as the Roundtable on Sustainable Biofuels (RSB) and Council on Sustainable Biomass Production (CSBP), and technical analysis approaches, such as the Center for Bioenergy Sustainability (CBES).

To generate a relevant, consistent, and widely applicable biofuel sustainability framework, we used a hybrid approach to select criteria and indicators that reflect the relevance of US government drivers, technical rigor of SME frameworks, and widely accepted results of existing SME- and consensus-based standards. We reviewed and integrated many of the current bioenergy frameworks (GBEP) and biofuel standards (CSBP and RSB). We then incorporated the US government driver and DoD mandate analysis with the identified biofuel sustainability frameworks and industry standards. We performed a qualitative principle component crosswalk (Figure 2-2) and merged the redundant pillars, criteria, and indicator areas.

This process generated a comprehensive but rather lengthy list of biofuel sustainability criteria (19), indicators (80), and possible metrics (271).

Figure 2-2. Sustainability Qualitative Principle Component Crosswalk

Microsoft Excel - Frameworks_Capture_122211.xlsx																			
	A	B	C	E	F	G	H	K	N	Q	T	W	Z	AC	AF	AI	AL	AO	
1	Org/Title:	DLA Energy Biofuels Study	Green Highlights:																
2	Source:	LMI	Newly Added to DLA Energy List																
3	Area of Focus:	Feedstock, Production, and Energy Use																	
4																			
5																			
6	Sustainability Pillar	Criteria	Indicators	Metrics	DLA Re	Common	DLA	MOU	EPA	DOE	DOE	USDA	CAAI	GBEF	ISO	CSBF	RSB	incip	6
7	Operational Sustainability	Suitability	Fuel Readiness Level		Yes	0													
8	Operational Sustainability	Suitability	ASTM Spec Met		Yes	2	Yes							Yes					
9	Operational Sustainability	Suitability	ASTM Spec Met	Energy Density	Yes	1	Yes												
10	Operational Sustainability	Suitability	ASTM Spec Met	Aromatics Content	Yes	2	Yes						Yes						
11	Operational Sustainability	Suitability	Operational Fuel Spec Met		Yes	2	Yes							Yes					
12	Operational Sustainability	Energy Security	Improve Fuel Properties		Yes	1				Yes									
13	Operational Sustainability	Energy Security	Improve Fuel Properties	Cold flow properties	Yes	1				Yes									
14	Operational Sustainability	Energy Security	Net Energy Balance / Efficiency		Yes	5	Yes			Yes		Yes	Yes	Yes	Yes				
15	Operational Sustainability	Energy Security	Net Energy Balance / Efficiency	energy input / energy output	Yes	5	Yes			Yes		Yes	Yes	Yes	Yes				
16	Operational Sustainability	Energy Security	Fossil Energy Use / Depletion		Yes	4	Yes	Yes						Yes	Yes				
17	Operational Sustainability	Energy Security	Fossil Energy Use / Depletion	fossil energy input / energy	Yes	3	Yes							Yes	Yes				
18	Operational Sustainability	Energy Security	Fossil Energy Use / Depletion	petroleum input / energy of	Yes	3	Yes							Yes	Yes				
19	Operational Sustainability	Availability	Feedstock / Fuel Production Capacity		Yes	4	Yes	Yes						Yes			Yes		
20	Operational Sustainability	Availability	Production Timetable		Yes	2	Yes	Yes											
21	Operational Sustainability	Availability	Distribution / Transportation Constraints		Yes	3	Yes	Yes						Yes					
22	Operational Sustainability	Availability	Feedstock Readiness Level		Yes	1							Yes						
23	Economic Sustainability	Energy Security	Energy Diversity		Yes	5	Yes	Yes		Yes		Yes	Yes	Yes					
24	Economic Sustainability	Macroeconomic	Economic Conditions		N/A	3	Yes										Yes		
25	Economic Sustainability	Macroeconomic	Economic Conditions	Access to Markets	N/A	2				Yes							Yes		
26	Economic Sustainability	Macroeconomic	Economic Conditions	Output and input markets	N/A	2				Yes							Yes		
27	Economic Sustainability	Macroeconomic	Economic Activity		Possible	2						Yes		Yes					
28	Economic Sustainability	Macroeconomic	Economic Activity	Gross value added	Possible	1								Yes					
29	Economic Sustainability	Economic Viability	Market Strategies		Possible	2				Yes							Yes		
30	Economic Sustainability	Economic Viability	Market Strategies	Long-term Market Strategy	Possible	1				Yes									
31	Economic Sustainability	Economic Viability	Market Strategies	Market information system	Possible	1											Yes		
32	Economic Sustainability	Economic Viability	Sustainability Practices / Natural Resource Account		Yes	2				Yes	Yes								
33	Economic Sustainability	Economic Viability	Trade		N/A	1				Yes									
34	Economic Sustainability	Economic Viability	Capital Investment Requirements		Yes	5	Yes	Yes		Yes				Yes			Yes		
35	Economic Sustainability	Economic Viability	Capital Investment Requirements	Return on Investment	Yes	1				Yes									
36	Economic Sustainability	Economic Viability	Capital Investment Requirements	Financing	Yes	1											Yes		
37	Economic Sustainability	Economic Viability	Capital Investment Requirements	Commercial financing system	Possible	1											Yes		
38	Economic Sustainability	Economic Viability	Capital Investment Requirements	Training and re-qualification	N/A	1								Yes					
39	Economic Sustainability	Economic Viability	Microfinance		N/A	1											Yes		
40	Economic Sustainability	Economic Viability	Project Viability		Possible	3	Yes					Yes					Yes		
41	Economic Sustainability	Cost / Price	Operational Costs (infrastructure, equipment, life)		Yes	3	Yes			Yes	Yes								
42	Economic Sustainability	Cost / Price	Operational Costs (infrastructure, equipment, life)	Cost of Production	Yes	1				Yes									
43	Economic Sustainability	Cost / Price	Incentive / Tax Factors		Yes	1	Yes												
44	Economic Sustainability	Cost / Price	Fuel Price		Yes	4	Yes	Yes		Yes	Yes								
45	Economic Sustainability	Cost / Price	Relative Petroleum Price		Yes	2	Yes	Yes											
46	Environmental Sustainability	Water	Water Quantity		Yes	8	Yes			Yes	Yes	Yes	Yes	Yes		Yes	Yes		
47	Environmental Sustainability	Water	Water Quantity	Source		1						Yes							
48	Environmental Sustainability	Water	Water Quantity	Legal compliance	Yes	1										Yes			
49	Environmental Sustainability	Water	Water Quantity	Use rights	N/A	2										Yes		Yes	
50	Environmental Sustainability	Water	Water Quantity	Alteration of natural flow	Possible	1												Yes	
51	Environmental Sustainability	Water	Water Quantity	Modification of the physical, chemical and biological equilibrium the natural watercourse had before the beginning of operations														Yes	
52	Environmental Sustainability	Water	Water Quantity	Irrigation	Possible	2										Yes	Yes		
53	Environmental Sustainability	Water	Water Quantity	Irrigation plan	Possible	1										Yes			
54	Environmental Sustainability	Water	Water Quantity	Salinity	Possible	2										Yes	Yes		
55	Environmental Sustainability	Water	Water Quantity	Precipitation	Possible	1				Yes									
56	Environmental Sustainability	Water	Water Quantity	Peak storm flow	Possible	1				Yes									
57	Environmental Sustainability	Water	Water Quantity	Seasonal flow regimes (water courses and streams)														Yes	
58	Environmental Sustainability	Water	Water Quantity	Minimum base flow	Possible	1				Yes									
59	Environmental Sustainability	Water	Water Quantity	Replenishment capacity of	Possible	2										Yes	Yes		
60	Environmental Sustainability	Water	Water Quantity	Water availability	Yes	3			Yes		Yes	Yes							
61	Environmental Sustainability	Water	Water Quantity	Water withdrawal	Yes	4	Yes			Yes			Yes				Yes		
62	Environmental Sustainability	Water	Water Quantity	Water consumption	Yes	5	Yes			Yes	Yes		Yes				Yes		
63	Environmental Sustainability	Water	Water Quantity	Relative Sufficiency / Conf	Yes	3	Yes					Yes					Yes		
64	Environmental Sustainability	Water	Water Quantity	Water use, efficiency, con	Yes	5						Yes	Yes	Yes		Yes	Yes		
65	Environmental Sustainability	Water	Water Quantity	Water management plans	Possible	2											Yes	Yes	
66	Environmental Sustainability	Water	Water Quality		Yes	10	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
67	Environmental Sustainability	Water	Water Quality	Precision agriculture	Possible	1											Yes		
68	Environmental Sustainability	Water	Water Quality	Use of wastewater for irrig	Possible	1											Yes		
69	Environmental Sustainability	Water	Water Quality	Water Quality Management	Yes	2											Yes	Yes	
70	Environmental Sustainability	Water	Water Quality	Management practices m	Possible	1											Yes		
71	Environmental Sustainability	Water	Water Quality	Waste Disposal	Possible	1											Yes		
72	Environmental Sustainability	Water	Water Quality	Treatment or recycling of waste water														Yes	
73	Environmental Sustainability	Water	Water Quality	Precipitation	Possible	1				Yes									
74	Environmental Sustainability	Water	Water Quality	Contamination of storm water														Yes	
75	Environmental Sustainability	Water	Water Quality	Contamination of water resources by untreated vinasse / (stillage)														Yes	
76	Environmental Sustainability	Water	Water Quality	Erosion	Yes	3			Yes	Yes						Yes			
77	Environmental Sustainability	Water	Water Quality	Suspended sediment conc	Yes	3			Yes	Yes							Yes		
78	Environmental Sustainability	Water	Water Quality	Total phosphorus (P) con	Yes	5			Yes	Yes			Yes			Yes		Yes	
79	Framework Summary List	Hybrid Framework w Metrics	DLA Energy Original Criteria	MOU Navv DOE USDA	EPA FTRC	DOE Biomass Program										Yes		Yes	

Criterion and Indicator Down-Selection

The list of indicators (and metrics) was quite comprehensive, but the number was overwhelming and lacked the focus necessary to effectively serve DLA Energy's intended end uses (procurement, technical review, and identification of information gaps).

To narrow the list, we reviewed the driver crosswalk, identified the indicator topics cited, and, then, categorized them by relevance, such as general (topic), direct (topic and biofuels), and metric proposed (topic- and biofuel-specific metric). The resulting statutory and policy analysis gave us three additional subcategories (statutes, government policy, and DoD and military service policy) for determining the relevance of the identified indicators. This analysis was then combined with that of the federal biofuels sustainability frameworks and industry standards.

Using these analyses, we assessed the applicability of each indicator across four components: (1) statutory relevance, (2) government policy relevance, (3) DoD and military service relevance, and (4) sustainability standards relevance. We summed the number of applicable statutes, policies, and standards, applying conditional formatting to quickly identify the highest frequency of relevance. A fifth component was the indicator's relevance to DLA Energy's mission and proposed roles. From our judgment and discussions with DLA Energy, each indicator was rated as high, medium-high, medium, low-medium, or low.

By applying these five components, we generated a high-priority indicator list (n=42) across all pillars and narrowed the number of priority indicators ("the green baker's dozen") in the environmental pillar (n=16). DLA Energy SMEs reviewed, validated, and finalized this hierarchy and indicator list. This framework was used to guide the further development of the overall sustainability architecture. The remaining medium-high, medium, low-medium, and low priority indicators are to be added later and integrated into the biofuel sustainability assessment as resources and technical data become available.

BIOFUEL SUSTAINABILITY ARCHITECTURE EVOLUTION

This study sought to develop advanced biofuel sustainability metrics, but metrics are only a means to an end. They must be developed for use in defined processes with an application and end use in mind to be meaningful. The ultimate intent is to aid DLA Energy in its biofuel procurement decisions, due diligence technical review, and identifying R&D needs, but we found it necessary to define and evolve a process-oriented context for using these sustainability metrics in a way that served DLA Energy's end-use roles.

Our team found that we needed to develop (with DLA Energy) a biofuel sustainability architecture. DLA Energy personnel needed a architecture in which to understand the advanced biofuel feedstock and conversion pathway, apply the

biofuel sustainability framework, assess and quantify biofuel sustainability metrics, and effectively communicate the results to DLA Energy technical personnel. This process architecture allowed us to develop recommendations on how this knowledge can be refined, institutionalized, and used to inform decisions and policies moving forward.

In close coordination with DLA Energy, we defined the specific end-use applications, stakeholders involved, and current best practices in sustainability. In Chapter 3, we expand on the sustainability drivers and their implications, and in Chapter 6, propose a biofuel sustainability architecture. We furnished foundational knowledge and a proposed architecture to support the DLA Energy roles, but moving forward, they will need to be refined and evolved, given the rapidly changing biofuel feedstock and conversion technology marketplace.

Chapter 3

Biofuel and Sustainability Policy

Laws, regulations, and executive branch policies define and provide the framework and drivers for energy security, biofuels, and sustainability. The associated definitions, priorities, mandates, and goals are the operating ground rules for all executive branch agencies, including DoD, the military services, and DLA Energy. From definitions of biomass, to production mandates and incentives, to environmental regulations and restrictions, this evolving framework sets the stage and national priorities for biofuel expansion and energy security. Federal statutes and regulations also emphasize economic, social, and environmental legislative priorities, some that directly apply to biofuels. Executive branch policy statements and EOs more explicitly define sustainability, what it includes, and the desired goals. They also identify and touch upon many of the criteria and indicators, even if not specifically focusing on operational biofuels.

This chapter introduces energy security, biofuels, and sustainability and the statutes, policy, and functional drivers that influence them. It does not include a recitation of every related statute, regulation, and policy, but sets the stage, identifies important implications, and furnishes the context for the remainder of the report. We briefly examine key policy drivers and their applicability in the construct of the DLA Energy biofuel sustainability framework. We summarize their relevance, explore key concepts and context, introduce the proposed sustainability framework to review the applicable federal policies, and focus on the most salient implications for these criteria.

POLICY AND ITS EXECUTION

As discussed in Chapter 2, federal statutes, regulations, and other policy documents govern energy security, biofuels, and sustainability. Federal government policy comes in a number of forms with varying detail, weight, and consequences. Laws authorize and fund executive branch regulations, federal agencies implement and fulfill associated requirements, and, if needed, judicial bodies review these drivers when their constitutionality, interpretation, or implementations are in question.

Congress passes statutes, known as public laws, and the President signs them into law. Those, such as EISA, provide a framework for achieving desired goals, giving executive branch agencies the legal authority to develop and issue regulations, which provide prescriptive requirements, administrative processes, and implementing actions for meeting the requirements of a given law. Laws and regulations often carry with them penalties, such as taxes, fines, or incarceration, but can also establish incentives and technical support programs. Executive branch

activities are balanced with Congress’s “power of the purse” and the resultant riders to appropriation bills, such as those focused on military biofuels.

Strategies, orders, and memorandums guide implementation of executive policies. Differing from regulations, these policy instruments communicate priorities, goals, and mandates within presidential authority. They are not generally legally binding, but nonconformance may result in the imposition of budgetary limits or negative performance ratings for organizations, such as OMB scorecards.

When questions arise regarding laws, policies, or their execution, the judicial branch may interpret their constitutionality, congressional intent, and regulatory execution at various levels up to the US Supreme Court.

DEFINING THE LANDSCAPE

EISA and its implementing regulation, RFS2, constitute the main statutory guidance on energy security, renewable biomass, and renewable biofuels. They are not descriptive (or conversely prescriptive) on energy security, but they *do* define biomass, fuels, and biofuels. Statutory and regulatory coverage of sustainability is limited, but EOs 13423 and 13514 define its means and ends.

Energy Security

Energy security is a national priority integral to US national security and economic prosperity. The Energy Policy Act of 2005 (EPAct 2005) cites it, and EISA focuses on it. Despite its growing importance, neither statute explicitly defines the term. EISA’s preamble *does* identify some core activities or means towards national energy independence and achieving energy security, such as

- increasing energy efficiency (buildings, vehicles, and products) and performance;
- increasing production of “clean renewable fuels”;
- reducing greenhouse gases; and
- protecting consumers.¹

Section 806 of EISA goes further by providing a “Sense of Congress” focused on renewable energy and its role in providing “national security, improved balance of payments, healthier rural economies, improved environmental quality, and abundant, reliable, and affordable energy for all citizens of the United States.”²

In terms of national energy security requirements, Section 933 requires the annual submission of a national energy security strategy report to Congress. New

¹ EISA, 110 United States Code (U.S.C.), (2007).

² Ibid.

presidential administrations are also required to submit a “comprehensive report on the national energy security of the United States.”³

In January 2007, President Bush signed EO 13423, “Strengthening Federal Environmental, Energy, and Transportation Management,” after EPCA 2005 but before EISA. EO 13423 does not explicitly mention or define energy security, but it confirms the focus on federal energy efficiency and management, petroleum use reduction, environmental quality, and fleet biofuel use, many of which were later codified in EISA. In October 2009, President Obama signed EO 13514, “Federal Leadership in Environmental, Energy, and Economic Performance,” which explicitly cites “energy security” as a key element of its overarching policy statement. EO 13514, however, did not provide an official definition for this concept.

Both federal statute and executive branch policy remain vague on national energy security but are more specific in the context of DoD energy security. In recent years, bipartisan congressional advocates have even established the Defense Energy Security Caucus with the stated mission to

educate members of Congress and the public about the strategic value of utilizing conservation, efficiency and sustainable energy sources for the US military; highlight and support established and emerging defense energy initiatives; and to help find solutions to energy challenges facing the Armed Forces and the Department of Defense.⁴

The National Defense Authorization Acts (NDAAs) of FY08–11 all cite energy security as an important priority but do not provide an explicit definition. However, NDAA FY12, Section 2821, Part (3)(A) does specifically define “‘energy security’ [as] having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet mission essential requirements.”⁵

As mentioned in Chapter 1, the 2010 QDR recognizes a strategic imperative to consider energy security and climate change because of their potential to impact national security and mission readiness.⁶ For DoD, energy security means having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs.⁷ Our military services largely rely on finite, petroleum-based fossil fuels, and this poses core mission sustainability challenge in the mid to long term. Tightening global petroleum supplies and geopolitical instability in some oil-producing nations contribute to steadily rising energy costs, price volatility, and difficulty in navigating a lean budget cycle. These

³ EISA, 110 U.S.C. §993 (2007).

⁴ US House of Representatives, Defense Energy Security Caucus, “Mission,” *Defense Energy Security Caucus*, desc.hinchey.house.gov/about/purpose-mission-goals.shtml.

⁵ EISA, 110 U.S.C. §2821 (2007).

⁶ DoD, *Strategic Sustainability Performance Plan, FY2010*, August 26, 2010.

⁷ US Secretary of Defense, *Quadrennial Defense Review Report*, (Washington, DC: February 2010), www.defense.gov/qdr/images/QDR_as_of_12Feb10_1000.pdf.

challenges are intensifying as the growing global demand for energy outstrips projected petroleum production and refining capacity.⁸

A 2009 joint article by the Center for Strategic and International Studies (CSIS) and World Resources Institute (WRI) lists energy security component factors.⁹ Focusing on those most relevant to biofuels, we distilled a working list of relevant functional attributes:

- ◆ Domestic production (or level of import)
- ◆ Energy diversity (of source and supplier)
- ◆ Economic viability (reliable and affordable)
- ◆ Market/price volatility
- ◆ Trade (geopolitical security, shipping lane security, and economics).

These conceptual foci helped validate several elements of our proposed sustainability framework, particularly its operational and economic pillars, and ensured we have consistently addressed and considered energy security.

Biomass, Fuels, and Renewable Biofuels

Whereas energy security is lacking conceptual clarity, US statutes and regulations explicitly define biomass and biofuels. In revisiting prior analyses, we found that EISA and its flow-down requirements in RFS2 are still the most current guidance on what is considered renewable biomass. Policy instruments offer some definitional guidance on fuel types, such as alternative, synthetic, and renewable. Biofuels, particularly, renewable biofuels are a subset of these categories and are elaborated below.

RENEWABLE BIOMASS FEEDSTOCK

Rather than listing acceptable feedstocks, EISA and RFS2 clearly define *renewable biomass*. This definition includes seven different categories of biomass sources (feedstocks) and applies additional caveats. These new limitations were a significant change from RFS1. The conditions placed on renewable biomass are generally aimed at encouraging feedstock sourcing that minimizes negative land use change and impacts. Table 3-1 shows the RFS2 renewable biomass definition, organized by source category and condition.

⁸ See footnote 6, this chapter.

⁹ Britt Childs Staley et al., *Evaluating the Energy Security Implications of a Carbon-Constrained US Economy*, (Washington, DC: Center for Strategic and International Studies, World Resources Institute, January 2009), csis.org/publication/evaluating-energy-security-implications-carbon-constrained-us-economy.

Table 3-1. RFS2 Biomass Definition by Source Category and Condition

Source	Condition
Planted crops and crop residue	Harvested from existing agricultural land cleared or cultivated prior to December 19, 2007, and that was nonforested and either actively managed or fallow on December 19, 2007
Planted trees and tree residue	From a tree plantation located on non-federal land (including land belonging to an Indian tribe or an Indian individual held in trust by the United States or subject to a restriction against alienation imposed by the United States) that was cleared at any time prior to December 19, 2007, and actively managed on December 19, 2007
Animal waste material and animal byproducts	
Slash and pre-commercial thinnings	From non-federal forestland (including forestland belonging to an Indian tribe or an Indian individual held in trust by the United States or subject to a restriction against alienation imposed by the United States) that is not ecologically sensitive forestland
Biomass	Obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, in an area at risk of wildfire
Algae	
Separated yard waste or food waste, including recycled cooking and trap grease, and materials described in § 80.1426(f)(5)(i)	

Source: 40 Code of Federal Regulations (CFR) 80.1401.

ALTERNATIVE, SYNTHETIC, AND RENEWABLE FUELS

Legislation, regulation, and federal policy are not as prescriptive for fuel types but do recognize three major categories of nonpetroleum liquid transportation fuels—alternative, renewable, and synthetic. These fuel categories primarily stem from language found in EPCA 1992, EPCA 2005, and EISA but also reflect other influences (Table 3-2).

Table 3-2. Definitional Sources

Fuel type	EPAct 1992, Sec. 301(2)	26 U.S.C. 6426(d)(2)	42 U.S.C. 13211(2)	10 CFR 490.2	10 CFR 500.2	EPAct 2005	RFS1	EISA 2007	RFS2	EO 13423	EO 13514
Alternative	✓	✓	✓	✓	✓	✓				✓	
Synthetic					✓						
Renewable						✓	✓	✓	✓		

In this study, we use previously defined categories:

1. *Alternative fuels* are transportation or mobility fuels not composed of or derived from liquid petroleum, including synthetic and renewable fuels.
2. *Synthetic fuels* are liquid hydrocarbon fuels produced from coal, natural gas, or biomass.
3. *Renewable fuels* are transportation or mobility fuels, used alone or blended with petroleum-based fuel, and wholly derived from “renewable biomass” or its decay products.¹⁰

As defined, renewable and synthetic fuels are not mutually exclusive. Some synthetic fuels, such as bio-SPK, may be generated using biomass.

“RENEWABLE” BIOFUELS

In the past, biofuels were simply considered to be fuels produced from a biomass feedstock. Per EPAct 2005, RFS1 broadly defines renewable biofuels as all motor vehicle fuels produced from renewable sources of plant or animal products or wastes. This definition includes

all motor vehicle fuels that are produced from biomass material such as grain, starch, oilseeds, animal, or fish materials including fats, greases and oils, sugarcane, sugar beets, tobacco, potatoes or other biomass (such as bagasse from sugar cane, corn stover, and algae and seaweed) [and] ... motor vehicle fuels made using a feedstock of natural gas if produced from a biogas source such as a landfill, sewage waste treatment plant, feedlot, or other place where decaying organic material is found.¹¹

¹⁰ DoD, *Opportunities for DoD Use of Alternative and Renewable Fuels*, 3-628E8C8, July 2011, energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf.

¹¹ EPAct, 109-58 U.S.C. (2005).

However, as a result of EISA's "renewable biomass" definition, RFS2 went on to narrowly define renewable biofuels, further limiting what may be used to meet its explicit volumetric requirements. RFS2 provides further categorical definitions based on conditions of feedstock sources, fuel end uses, and life-cycle GHG emissions. The new conditions placed on renewable fuels inherently introduced sustainability criteria and metrics not part of the earlier RFS1 biofuels definition.

Both EISA and RFS2 defined renewable [bio]fuel as

a fuel which meets all of the requirements of paragraph (1) of this definition: (1)(i) Fuel that is produced from renewable biomass. (ii) Fuel that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel, heating oil, or jet fuel. (iii) Has life-cycle greenhouse gas emissions that are at least 20 percent less than baseline life-cycle greenhouse gas emissions, unless the fuel is exempt from this requirement pursuant to §80.1403.¹²

This definition requires renewable fuels to have lifetime GHG emissions 20 percent lower than a baseline (see "Environmental Sustainability"). It did, however, expand the terms to include all *transportation fuels*, defined as "fuel for use in motor vehicles, motor vehicle engines, nonroad vehicles, or nonroad engines (except fuel for use in ocean-going vessels),"¹³ rather than just fuel for motor vehicles.

This definition both narrows the subset of possible pathways considered renewable biofuels *and* expands the range of fuel products it covered. However, jet and marine diesel fuels—the military services' largest fuel needs—are not included in volumetric mandates (or excluded, in the case of marine diesel). Given the broader importance of middle distillate fuel products, the RFS2 program recently clarified "the definition of renewable diesel to explicitly include jet fuel."¹⁴ This answered questions concerning the use of jet fuels for renewable identification number (RIN) credits and helped level the playing field between middle distillate diesel and jet biofuels in terms of volumetric mandates. EPA subsequently received "adverse public comments" on this direct rule and, as a result, withdrew it as of March 5, 2012.^{15,16} Action is pending on new rulemaking that considers these adverse comments.

¹² EISA, 110-140 U.S.C. (2007).

¹³ Ibid.

¹⁴ EPA, OTAQ, *EPA Issues Direct Final Rule for Additional Qualifying Renewable Fuel Pathways Under the RFS2 Program*, EPA-420-F-11-043 (Washington, DC: November 2011), www.epa.gov/otaq/fuels/renewablefuels/documents/420f11043.pdf.

¹⁵ US Federal Register, *Regulation of Fuels and Fuel Additives: Identification of Additional Qualifying Renewable Fuel Pathways Under the Renewable Fuel Standard Program*, EPA-HQ-OAR-2011-0542 (Washington, DC: March 5, 2012), www.gpo.gov/fdsys/pkg/FR-2012-03-05/pdf/2012-5256.pdf.

¹⁶ EPA, "Renewable Fuels: Regulations & Standards," *Fuels and Fuel Additives*, www.epa.gov/oms/fuels/renewablefuels/regulations.htm.

In this study, we focus on alternative and synthetic biofuels (jet and diesel fuels), including their upstream conversion and renewable biomass feedstock pathways. Of these, we primarily consider “drop-in” (interchangeable with conventional fuels) operational biofuels.

We found that DLA Energy has the flexibility to utilize the broader RFS1 definition of biofuels but with the understanding that such use requires additional consideration of the economic disincentives for products not generated from renewable biomass or considered a renewable biofuel under the RFS2 program, such as some Section 526-compliant products generated via coal-biomass-to-liquid. We do not specifically address synthetic fuels derived from non-biomass feedstocks, but these could be assessed using our proposed sustainability architecture.

Sustainability

In Chapter 1, we ask, “What is sustainability [particularly in the context of operational biofuels]?” In 1987, the Brundtland Commission defined sustainable development, which was later (1992) elaborated in the internationally accepted Agenda 21 Principles. These provide a direction but reflect a focus on international development and human security concerns.

One could argue that the preamble of the Constitution lays out the most compelling reason to consider sustainability: “provide for the common defence, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our Posterity.”

More than 100 years ago, President Theodore Roosevelt championed federal government conservation of resources and stewardship of our Nation’s resources—fiscal, natural, and otherwise. Section 2 of the National Environmental Policy Act (NEPA) of 1969 expanded this duty to the environment and codified the federal government’s mandate to

encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation.¹⁷

Aside from these overarching mandates, federal statutes and regulations are largely silent on defining sustainability but do focus on sustainability’s functional pillars or “triple bottom line” (economic, environment, and social).¹⁸ We found no statutory mandates driving national sustainability but did find that executive

¹⁷ NEPA, 42 U.S.C. § 432 (1982), ceq.hss.doe.gov/nepa/regs/nepa/nepaeqia.htm.

¹⁸ DOE, Office of Environmental Policy and Assistance, *Crosswalk of Sustainability Goals and Targets In Executive Orders and Statutes*, December 2, 2009, www.fedcenter.gov/_kd/go.cfm?destination=ShowItem&Item_ID=14107.

branch policy has defined and encouraged agencies to use this aim, process, and analytical paradigm.

The G.W. Bush and Obama administrations issued EOs 13423 and 13514, respectively, which not only define federal sustainability but also set numerous goals, targets, and mandates that have driven federal activity toward this end. Both EOs are in effect and define sustainability as

mean to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations.^{19,20}

EO 13423 first mandated the incorporation of mission sustainability into departmental policies and established goals and metrics, which were affirmed by provisions in EISA.²¹ EO 13514 went further, mandating greater leadership visibility and priority by establishing SSOs, requiring departmental SSPPs, and calling for an expanded OMB sustainability scorecard.²²

Each federal agency has a unique mission and role, which lead to numerous departmental and agency-specific definitions of sustainability. However, definitional semantics aside, all departments and agencies have increasingly focused on achieving greater sustainability for their core mission and by optimizing their operating performance across economic, environmental, and social aspects and impacts. The “economic” part of this equation first refers to good stewardship of agency financial resources while maximizing positive economic outcomes for the broader national economy. The “environmental” components focus on natural resource stewardship, improving efficiency and performance, and reducing negative impacts on human health, natural resources, and the broader environment. The social aspects and outcomes may be viewed as specific requirements or encouraged outcomes, depending on the agency’s mission responsibilities. Depending on perspective, sustainability and these pillars can be viewed as “ends,” “ways,” or “means” or all of the above.

The EOs definition of sustainability identifies the policy ends: desired objectives or conditions. We primarily consider sustainability as the conceptual “way,” an analytical lens through which to understand the relevant aspects, impacts, and risks of a particular “means,” in this case, operational biofuels.

¹⁹ US Federal Register, *Strengthening Federal Environmental, Energy, and Transportation Management*, EO 13423, January 24, 2007, www.gpo.gov/fdsys/pkg/FR-2007-01-26/pdf/07-374.pdf.

²⁰ US Federal Register, *Federal Leadership in Environmental, Energy, and Economic Performance*, EO 13514, October 5, 2009, www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf.

²¹ Federal Facilities Environmental Stewardship & Compliance Assistance Center, “Sustainability,” *FedCenter*, www.fedcenter.gov/programs/sustainability/.

²² See sustainability.performance.gov/.

Federal statutes, regulations, and EOs related to sustainability as a means to focus on federal facility performance (buildings, equipment, etc.), federal activity pollution prevention (P2) and compliance, bio-based product procurement,²³ and government fleet vehicle efficiency and biofuel use. In almost all cases, operational fuels are excluded or explicitly exempt from their defined goals or ends.

Nevertheless, this study focuses on operational biofuels. Sustainability is the analytical lens or way elaborated in the remainder of this report. It will help DLA Energy better understand the relevant aspects and impacts of the operational biofuel means and their upstream supply chain risks. It will also ensure progress toward the military services, DoD, and broader US strategic ends.

BIOFUEL SUSTAINABILITY POLICY

Government directives utilize various mechanisms to reach intended goals related to biofuel sustainability. A number of statutes set requirements for the production and use of types or volumes of biofuels, some of which carry the penalty of non-compliance fines. These mandates generally have the effect of creating demand for the fuels, which in turn creates demand for feedstocks and equipment up the fuels' production supply chains. The intended results are increased production capacity, increased economies of scale, reduced costs, minimized environmental impacts, and, ultimately, displacement of conventional petroleum-based fuels for energy security, trade, and rural development purposes.

Depending on the stipulations—such as feedstock definitions or production process requirements—these types of mandates may impact the sustainability of biofuels. Statutes that do not specifically attempt to minimize the economic, environmental, and social impacts of fuel production and its use may have the effect of increasing production volumes but may promote unsustainable methods, resulting in environmental deterioration or unintended social impact. On the other hand, statutes that specify sustainability-related metrics or benchmarks may help to standardize and improve the economics of biofuel types that limit or reduce negative economic, environmental, or social impacts.

Federal laws and appropriations bills may also include subsidies aimed at supporting various sectors of the biofuels industry. Subsidies come in various forms such as loan guarantees, tax credits, and grants. These require recipients to perform certain tasks or meet specified guidelines related to biofuels production, distribution, or use as a condition of receiving the benefit or award. These subsidies are designed to reduce costs along the supply chain and, ultimately, incentivize increased production and expanded use of biofuels. Increases in production volume and scale tend to offer improved efficiencies and make biofuels more competitive with conventional fuels as the industry matures. Further, when the stipulations placed on subsidy recipients involve advances in biofuel sustainability, industry can more quickly respond to and incorporate the new best practices.

²³ Food, Conservation, and Energy Act (FCEA), 110-246 U.S.C. §2067 (2008), www.gpo.gov/fdsys/pkg/PLAW-110publ246/pdf/PLAW-110publ246.pdf.

Statutes may also specify environmental protection criteria. Biofuel production and use are governed by a framework of regulations that establish threshold environmental criteria designed to protect air, water, land, and other natural resources. They aim to ensure that adverse environmental impacts related to production and use are reduced and limited to acceptable levels. By establishing minimum standards, they become baseline biofuel sustainability metrics.

Executive branch biofuel policy may not only implement congressional intent but act as a platform to promote further action. In March 2011, President Obama issued the *Blueprint for a Secure Energy Future*,²⁴ which lays out a broad strategy for addressing the country's energy independence and clean energy challenges. Among a range of approaches, it encourages easing demand for fossil fuels through increases in biofuel production. It highlights multiple ongoing international collaborative efforts to expand bioenergy development, identify sustainable biofuel development practices, and promote clean energy technology deployment. It promotes the benefits of transitioning from 10 percent to 15 percent ethanol content in gasoline products. It not only describes DOE and USDA advanced biofuel grants and loan programs but establishes a goal of constructing four commercial-scale advanced biorefineries by 2013. It also calls for interservice (DoD) collaboration to accelerate drop-in replacements for diesel and jet fuel.

In April 2012, President Obama issued the *National Bioeconomy Blueprint* to state strategic objectives and describe efforts toward strengthening the role of biological sciences in the US economy.²⁵ It highlights technological advances in biofuels as a trend among federal agencies and seeks to encourage public-private partnerships in this area. Shortly after its release, DOE announced that up to \$15 million in funding would be available for advanced development of bio-oil prototypes, in conjunction with the blueprint. (Bio-oils are biomass-based feedstock for several advanced, drop-in biofuel pathways.²⁶) Together, these two blueprints provide a detailed picture of federal intentions to promote the expansion of US biofuels.

To feed into the biofuel and sustainability crosswalk analysis (Chapter 2), we reviewed statutes and policies (Table 3-3).

²⁴ US White House, *Blueprint for a Secure Energy Future*, (Washington, DC: March 30, 2011), www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf.

²⁵ US White House, *National Bioeconomy Blueprint*, (Washington, DC: April 2012), www.whitehouse.gov/sites/default/files/microsites/ostp/national_bioeconomy_blueprint_april_2012.pdf.

²⁶ DOE, "Energy Department Announces Up to \$15 Million to Research Biomass-Based Supplements for Traditional Fuels," *Energy Efficiency & Renewable Energy News*, apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=707.

Table 3-3. Biofuel Statutes and Policies

Statutes reviewed	Policies reviewed
NEPA 1970	EO13423
Omnibus Budget 1980	EO 13514
Clean Air Act (CAA) 1990	Presidential Memorandum on Biofuels
Omnibus Budget 1990	President's Bioeconomy Blueprint
Clean Water Act 1972	President's Blueprint for a Secure Energy Future
Emergency Planning and Community Right-to-Know Act 1986	
Biomass Research and Development Act 2000	
Farm Security and Rural Investment Act of 2002 (2002 Farm Bill)	
Jobs Act 2004	
Environmental Policy Act 2005	
Tax Relief and Health Care Act of 2006	
EISA 2007	
Food, Conservation, and Energy Act 2008 (2008 Farm Bill)	
American Reinvestment and Recovery Act	
Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010	

We leveraged a preliminary biofuel sustainability construct developed for a joint DOE and USDA Sustainability of Biofuels Workshop,²⁷ and we expanded it to incorporate the aforementioned sustainability definitions, which yield four dimensions, or pillars, of sustainability (operational, economic, environmental, and social). Using this preliminary construct, we reviewed and analyzed the statutes and policies in Table 3-3 to develop a crosswalk against pillars and an evolving list of aspects and issues. We compile and assimilated common biofuel sustainability aspects and impacts to yield criteria areas.

SUSTAINABILITY FRAMEWORK AND DRIVER ANALYSIS

Once the crosswalk analysis yielded criteria, we developed a draft biofuel sustainability framework (Figure 3-1).

²⁷ USDA and DOE, *Sustainability of Biofuels Future Research Opportunities Report from the October 2008 Workshop*, DOE/SC-0114 (April 2009), genomicscience.energy.gov/biofuels/sustainability/.

Figure 3-1. Draft Sustainability Framework



Each of the *pillars* is category in the framework, composed of one or more criteria. *Criteria* refer to secondary categories that describe the common aspect or impact elements and are composed of one or more indicators. (In Chapter 6, we detail the draft biofuel sustainability framework, its criteria, and its indicators.)

Using this draft framework, we analyzed the policy against these common criteria and assessed its relevance in terms of general topic, specific to biofuels, and identified metric(s). In general, we found many of the policies only generally apply to biofuels or certain sustainability criteria, and some of them have been superseded by more recent legislation or may be superseded by the release of this report (the 2012 Farm Bill, for example).

However, when we found policy that specifically applied to biofuels, we analyzed it in detail and determined the implications for our indicators and potential metrics. The remainder of this chapter summarizes drivers by pillar and discusses the most relevant implications.

Operational Sustainability

In this subsection, we discuss how particular statutes and policies drive biofuels' role in operational sustainability. For our purposes, the key functional criteria that characterize the operational sustainability pillar are as follows:

- ◆ Energy security
- ◆ Fuel suitability
- ◆ Fuel availability.

Table 3-4 shows the biofuel-related statutes and policies that may impact operational sustainability by addressing energy security, fuel suitability, and fuel availability concerns.

Table 3-4. Operational Pillar Relevant Statutes and Policy

Criteria	Statute	Policy
Energy security	BRDA 2000, Sections 302, 304, and 307 Farm 2002, Section 9003 EPA 2005, Sections 201, 369, 701, 931, 932 and 941 EISA 2007, Sections 202 and 224 FCEA 2008, Section 9008	EO13423, Sections 2 and 3 EO 13514, Sections 1, 2, and 12 OMB Scorecard
Fuel suitability	CAA 1990, Section 211 Farm 2002, Section 9010	
Fuel availability	BRDA 2000, Sections 302 and 307 Farm 2002, Section 9002 EPA 2005, Sections 1501 and 941 EISA 2007, Section 202 FCEA 2008, Section 9008	

Note: BRDA = Biomass Research and Development Act and FCEA = Food Conservation and Energy Act.

In reviewing statutes and policies, we found they directly address all operational sustainability criteria broadly but are prescriptive primarily in mandates to encourage fuel availability and, to a lesser extent, fuel suitability. They often mention energy security as a priority, but do not explicitly define it.

ENERGY SECURITY

Biofuel statutes and policies cite energy security challenges. They encourage domestic biofuels production to reduce reliance on foreign oil and expand energy supply to meet economic and consumer demands. The price and availability of conventional petroleum fuel from foreign sources fluctuates greatly due to geopolitical influences or natural disasters. Laws and policies, such as EISA and EOs, explicitly seek to expand production of domestic feedstocks and biofuels to create

a more diversified and robust fuel market to limit US exposure to fuel price and supply fluctuations. While not cited in existing legislation, policy support for the development of advanced, drop-in biofuel production capacity and its use for aviation fuels has increasingly focused on defense energy security, including efforts to decrease supply chain vulnerability, increase diversification of fuel products, and buffer defense budget impacts of petroleum price volatility.

FUEL SUITABILITY

Given its technical and scientific nature, fuel suitability is typically addressed through original equipment manufacturer (OEM) working groups, industry standard organizations, or military service programs responsible for setting specification. ASTM International committees have purview over industry fuel specification in the United States and have been key in moving new drop-in biofuel products into commercially acceptable fuels. For example, ASTM International, Standard D7566, “Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons,” contains technical requirements and characteristics, such as the flash and freezing points, for F-T synthetic paraffinic kerosene (SPK) fuels and the more recently approved HEFA fuel blend stocks.²⁸ Military fuel specifications are maintained by their respective military service owner, which is why all have been working on the fuel qualification and weapons platform certification efforts widely publicized in recent years.

However, both the 1990 CAA and the 2002 Farm Bill call for federal regulators to standardize the definition of biodiesel. These laws were less prescriptive from a technical specification standpoint but more a call for action. Given definitional uncertainty, inconsistent biodiesel products, resultant problems with use, and OEM warranty issues hindered production and use. These statutes encourage regulators to establish a definition and, as a result, overcome the associated market barriers, facilitating industry-wide production, adoption, and use.

FUEL AVAILABILITY

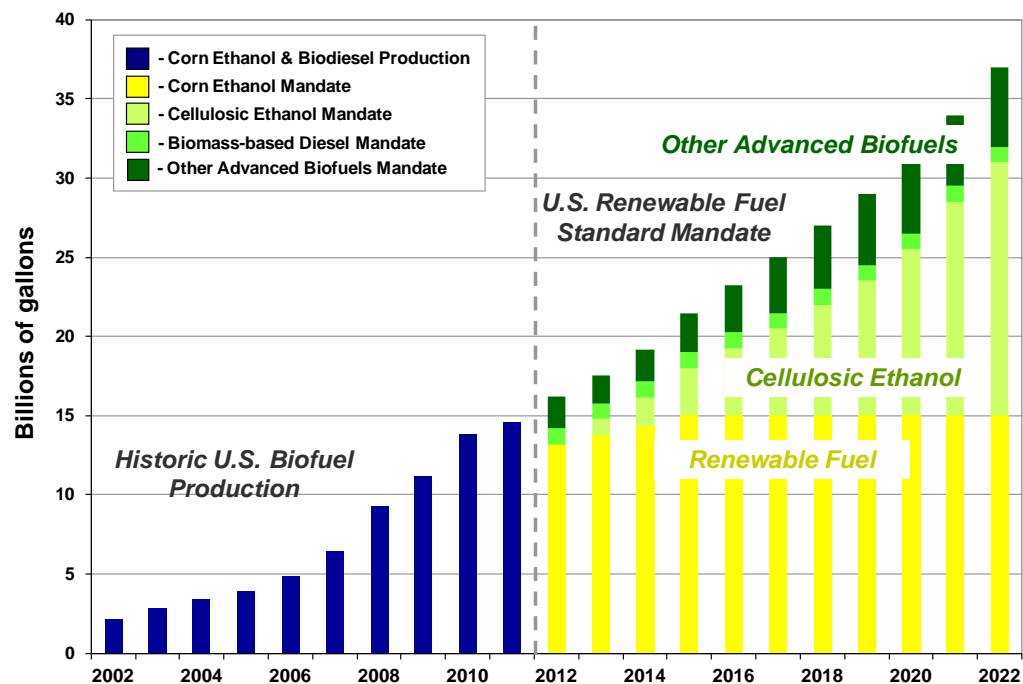
At their core, most policies promote alternative and biofuel availability, whether through greater production or mandated use. To promote the production, EPA 2005 established the initial RFS1, which required EPA to set a minimum volume of biofuels to be sold or dispensed by refiners, importers, or blenders each year in 2007–12.²⁹ RFS1 established a means of generating a known level of demand for fuels intended to be more sustainable than conventional fossil fuels, thus creating market certainty and encouraging investment in biofuel production.

²⁸ Cicely Enright, “Aviation Fuel Standard Takes Flight,” *ASTM International*, www.astm.org/SNEWS/SO_2011/enright_so11.html.

²⁹ EPA, OTAQ, *EPA Finalizes Regulations for a Renewable Fuel Standard (RFS) Program for 2007 and Beyond*, EPA420-F-07-019 (Washington, DC: April 2007), www.epa.gov/otaq/renewablefuels/420f07019.pdf.

EISA later built on RFS1, introducing a revised standard known as RFS2. RFS2 increases the volumetric requirements for 2008–22, expands the covered fuel types, establishes subcategory requirements within the overall volumetric requirement, creates new definitions for biofuels, and introduces GHG emissions thresholds.³⁰ Figure 3-2 shows the volumetric requirements.

*Figure 3-2. RFS2 Biofuel Production Requirements
(Billion Gallons)*



Note: Fuel quantities represent “neat,” rather than blended, fuel.

RFS2 expanded the types of vehicle fuels covered under the volumetric requirement. RFS1 required only that on-road vehicle fuels sold be used to establish the volumetric requirements, but it allowed fuels produced for other end uses, such as off-road, to be used to help meet the annual sales requirements.³¹ RFS2 expanded the volumetric requirement calculation to include diesel and nonroad fuels. As in RFS1, noncovered fuels, such as aviation and ocean-going fuels, were not considered in determining the volumetric standard, but they may be used to meet the sales requirement.³²

³⁰ Ibid.

³¹ US Federal Register, *Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program*, EPA-HQ-OAR-2005-0161 (Washington, DC: May 1, 2007), www.epa.gov/otaq/renewablefuels/rfs-finalrule.pdf.

³² US Federal Register, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program*, EPA-HQ-OAR-2005-0161 (Washington, DC: March 26, 2010), www.gpo.gov/fdsys/pkg/FR-2010-03-26/pdf/2010-3851.pdf.

Ethanol is mainly used as an oxygenate additive in gasoline. Before EPA approval, the agency conducted extensive technical evaluations to rule out potential negative consequences. Until recently, the ethanol demand for use as an oxygenate in gasoline (E10) has largely absorbed (~14 billion gallons annually) the volumetric production mandated by RFS2. However, with the E10 blend wall approaching, EPA began approving applications in April 2012 to increase the amount of ethanol blended with gasoline from 10 to 15 percent for use in model year 2001 and newer cars and light trucks. EPA's recent approval of 15 percent blends could result in a significant increase in the fuel market's capacity to absorb (higher E15 blend wall) the additional ethanol production mandated by the RFS2 volumetric mandates.

RFS1 and RFS2 have resulted in significant growth in biofuel use as an additive to convention gasoline blends (effectively E10 and next E15). However, other federal policies, including those for DoD, has prompted biofuel (and reduce petroleum) use in non-tactical fleet vehicles. In January 2007, President Bush signed EO 13423, which seeks to improve the environmental sustainability of federal operations.³³ In addition to establishing goals for energy efficiency, sustainable buildings, recycling, electronics stewardship, and water conservation, it encourages increased use of renewable fuels in federal vehicle fleets and facilities. EO 13514, later signed by President Obama, built on EO 13423, establishing additional GHG reporting and mitigation requirements. It also maintains and extends requirements under EO 13423 to annually increase the use of alternative fuels by 10 percent compared with the previous year.³⁴ EO 13514 stipulates that biogenic CO₂ emissions associated with biofuels use are not subject to reduction goals, so replacing conventional fuels with biofuels helps meet both GHG reduction *and* alternative fuel use requirements. Neither EO specifies sustainability metrics related to biofuels production or use, but the requirements to reduce GHG emissions and increase biofuel use inherently support further development of the biofuel market by creating additional market demand.

Economic Sustainability

In this subsection, we discuss the implications of the relevant statutes and policies on biofuels and their economic sustainability. For our purposes, the functional criteria that characterize the economic sustainability pillar are as follows:

- ◆ Economic viability
- ◆ Cost/price

Table 3-5 lists the statutes and policies generally or specifically relevant to biofuels and economic sustainability.

³³ See footnote 19, this chapter.

³⁴ See footnote 20, this chapter.

Table 3-5. Economic Pillar Relevant Statutes and Policies

Criteria	Statute	Policy
Economic viability	BRDA 2000, Sections 302, 304, and 307 Farm 2002, Sections 9003 and 9010 EPA 2005, Section 941 FCEA 2008, Section 9008	EO 13514, Sections 2 and 13 OMB Scorecard
Cost and price	BRDA 2000, Sections 302, 304, and 307 Farm 2002, Section 9002 EPA 2005, Section 942 EISA 2007, Sections 202 FCEA 2008, Section 9008 et al.	

Most of these statutes and policies seek to further the development, viability, and competitiveness of the US domestic biofuel industry, trying to improve its economic sustainability through several mechanisms. They specify and fund provisions for addressing both economic viability and cost/price criteria.

Federal laws and appropriations bills frequently include subsidies—such as grants, loan guarantees, and tax credits—supporting various sectors of the biofuel industry. The subsidies require the recipients to perform certain tasks or meet specified guidelines related to biofuel production, distribution, or use to receive the award, guarantee, or tax benefit. On the production side, increases in production volume and scale tend to improve efficiencies and make biofuels more competitive with conventional fuels, contributing to greater economic viability—in most cases. Other subsidies have the effect of reducing costs along the supply chain and, ultimately, incentivize increased use and production of biofuels.

Subsidies directly affect biofuel economic sustainability criteria. For economic viability, grants and loan guarantees are provided to producers, transporters, or biorefiners along the supply chain. Cost and price incentives, tax credits, and RIN payments all have implications for the end purchaser of the biofuel product.

ECONOMIC VIABILITY

Compared with petroleum, the US biofuel industry is a newcomer and still maturing its technologies, business models and supply chains. Statutes, regulations, and policies aimed at helping biofuels compete with conventional fuels focus on the economic viability of the industry. Grants and loan guarantee programs have been established and funded to reduce barriers to market entry, such as financing risk, and mitigate costs that inhibit industry maturation and growth. These mechanisms can spur the development of new technologies and support industry maturation, diversify the industry base, and create new jobs in more fields. Initial investments via grants and loan guarantees can help to support long-term decreases in production costs, which ultimately reduce consumer prices and move the industry toward viability. However, such subsidies can also negatively affect economic sustainability if market efficiencies do not materialize.

In such cases, the industry recipients come to depend on subsidies to prop up the industry and do not survive once the programs expire. That said, as the biofuel market matures, multiple producers, broader markets, and price competition all increase and help the industry to become more robust and develop greater economic viability. In this context, the following subsections identify and further discuss key grant and loan guarantee programs applicable to the biofuel industry.

Grants

DOE's Office of Energy Efficiency and Renewable Energy (EERE) manages the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, which promote small business innovation across a range of alternative energy and efficiency areas. DOE set aside \$9 million to fund the programs in 2012 within eight categories, including advanced manufacturing, energy-efficient buildings, biomass, hydrogen and fuel cells, solar energy, and wind and water power technologies.³⁵

Through various statutes, the EERE-administered biomass program offers a range of grants to fund R&D toward the production of fuels, electricity, chemicals, and other biobased products. A portion of the annual funding goes to biofuels; the overall program received \$220 million in 2010 and \$175 million each in 2011 and 2012, respectively.

USDA's National Institute of Food and Agriculture provides grants through a program established by the BRDA of 2000 and modified under the 2008 Farm Bill.³⁶ The program offers R&D grants for a range of activities aimed at advancing knowledge related to agriculture, including biodiesel and ethanol demonstration plants. Congress appropriated \$78 million for 2009–11 and \$40 million for 2012,³⁷ when it is scheduled to end.

The 2008 Farm Bill authorizes grants under USDA's Repowering Assistance Program, which directly funds biorefineries to reduce fossil fuel use or increase the amount of renewable biomass used for their own operations.³⁸ Award amounts are based in part on the amount of fossil fuels replaced by renewable biomass systems and the cost-effectiveness of the systems. Although authorized through 2012, \$50 million in total funding was appropriated only in 2009 and 2010. The program is currently scheduled to terminate at the end of 2012.

³⁵ DOE, "Energy Department Announces Funding for Small Business Innovation Research in Energy Efficiency and Renewable Energy," *Energy Efficiency & Renewable Energy News*, apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=708.

³⁶ USDA, "Recently opened grants," *National Institute of Food and Agriculture*, www.csrees.usda.gov/fo/recentReleasedGrants.cfm.

³⁷ Brent D. Yacobucci, *Biofuels Incentives: A Summary of Federal Programs*, R40110 (Washington, DC: Congressional Research Service, January 11, 2012).

³⁸ USDA, "Repowering Assistance Program," *Rural Development*, www.rurdev.usda.gov/BCP_RepoweringAssistance.html.

The USDA Rural Energy for America Program (REAP) program has a grant-making component in addition to the loan/loan guarantees discussed above. As with the loans, the grants help agricultural producers and rural small businesses to integrate renewable energy systems or implement energy-efficiency measures into their operations. In total, both grant and loan programs received \$235 million in 2009–11 and \$25.4 million in 2012, when the programs are set to expire.³⁹

The Value Added Producer Grant program, administered by USDA’s Rural Business Cooperative Service, encourages the introduction of new products, expands marketing opportunities, and increases producer income related to bio-based product offerings. The program is authorized up to \$40 million annually; in 2011, Congress appropriated \$37 million.⁴⁰ The program provides “[g]rants [that] may be used for planning activities [or] for working capital for marketing value-added agricultural products and for farm-based renewable energy.”⁴¹

Loan Guarantees

Through loan guarantees, the federal government takes on the risk of loan default for relatively high-risk technology development projects. The projects are generally higher risk because they are new and untested. Without a guarantee, such risk results in high loan costs, which often prohibit companies carrying out the projects, but with the guarantee, cutting-edge technologies can potentially be brought to market at lower cost.

Title XVII of EAct 2005 created DOE’s Loan Guarantee Program, which aims to accelerate the commercialization of innovative clean energy technologies that reduce air pollution and GHG emissions compared with conventional technologies.⁴² It covers a range of technologies, including wind and solar projects; for biofuels, it has guaranteed a \$132 million loan to Abengoa Bioenergy Biomass for the construction of a 25-million-gallon-per-year cellulosic ethanol plant in Hugoton, KS. The plant begins operation in 2013.

In addition, EAct 2005, Sections 1510, 1511, and 1516, establishes multiple DOE loan guarantees for ethanol and commercial byproducts from cellulose, municipal solid waste, and sugarcane. However these loan guarantees have not received appropriations to begin operation.⁴³

The 2008 Farm Bill authorized the USDA Biorefinery Assistance loan guarantee program to support the construction and improvement of commercial-scale

³⁹ See footnote 37, this chapter.

⁴⁰ US Federal Register, *Announcement of Value-Added Producer Grant Application Deadlines*, (Washington, DC: June 28, 2011), www.gpo.gov/fdsys/pkg/FR-2011-06-28/pdf/2011-16121.pdf.

⁴¹ USDA, “Value-Added Producer Grants,” *Rural Development*, www.rurdev.usda.gov/BCP_VAPG_Grants.html.

⁴² DOE, *Loan Programs Office*, lpo.energy.gov/.

⁴³ EAct, 109-58 U.S.C. §1510, 1511, 1516 (2005).

biorefineries for qualifying advanced technologies.⁴⁴ Technologies must convert feedstocks from renewable biomass other than corn kernel starch, including cellulose, sugar, crop and animal waste, vegetable and animal fats, and landfill waste gases. Congress appropriated \$245 million for 2010 until expended, but did not appropriate funds for 2012. The program is currently schedule to expire at the end of 2012.

The 2008 Farm Bill also authorized Renewable Energy Systems and Energy Efficiency Improvement loan and loan guarantees under USDA's REAP. REAP supports the purchase, installation, and construction of renewable energy generation systems and energy efficiency improvements by agricultural producers and rural small businesses. It includes bioenergy projects to produce fuel from biomass. The program is likewise scheduled to expire at the end of 2012.

COST AND PRICE

From a perspective of cost and price, incentives and tax credits mitigate some of the costs of feedstocks, production, and infrastructure across the biofuel life-cycle. We briefly summarize these tax credits, deductions, and subsidies but note that some have already expired or will phase out shortly. Depending on the 2012 Farm Bill and its appropriations, many of these programs may or may not apply moving forward, but their final disposition is uncertain. Finally, RINs and their market price can also impact cost and price, particularly in fuel categories where production is lagging behind RFS2 volumetric requirements.

Tax Credits and Deductions

The 2004 Jobs Act created the Volumetric Ethanol Excise Tax Credit (VEETC) and Biodiesel Tax Credit. Under VEETC, gasoline suppliers that blend ethanol into the gasoline they sell were eligible for a blender credit worth \$0.45 per gallon of ethanol blended. In addition, the act instituted the Biodiesel Tax Credit, which allowed producers of biodiesel or biodiesel blends to claim a \$1.00 per gallon of biodiesel tax credit.⁴⁵ Both programs, managed by the Internal Revenue Service (IRS), expired at the end of 2011, but are being considered for inclusion in the 2012 Farm Bill being negotiated by Congress.

The 1990 Omnibus Spending Bill established the small ethanol producer tax credit (PTC), which was last extended in the 2010 Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act. Under the law, ethanol producers with less than 60 million gallons per year of production capacity could claim \$0.10 per gallon of ethanol for the first 15 million gallons produced. The ability to claim the credit ended in December 2011.⁴⁶

⁴⁴ USDA, "Biorefinery Assistance Program," *Rural Development*, www.rurdev.usda.gov/BCP_Biorefinery.html.

⁴⁵ American Jobs Creation Act, 108-357 U.S.C. §301 (2004).

⁴⁶ Omnibus Budget Reconciliation Act, 101-508 U.S.C. (1990).

EPAct 2005 established the Small Agri-Biodiesel PTC. Similar to the small ethanol PTC, producers with less than 60 million gallons of capacity were allowed to take a \$0.10 per gallon credit for the first 15 million gallons of biodiesel produced in a given year.⁴⁷ It also expired at the end of 2011.

EPAct 2005 also created the alternative fuel infrastructure tax credit, which allowed businesses installing fueling equipment for E85 and B20 (minimum), among other alternative fuels, to take a tax credit based on the cost of the equipment. For equipment installed after January 2011, 30 percent of the cost up to \$30,000 for equipment was eligible.⁴⁸ The program expired at the end of 2011, but industry representatives are working to reinstitute it through legislation being considered in Congress.

EPAct 2005 established the special depreciation allowance for cellulosic biofuel plant property. Under the provision of the law, new facilities producing biofuels from cellulosic feedstocks may take a 50 percent depreciation deduction in the first year of operation. The allowance is set to expire in January 2013.⁴⁹

The renewable diesel tax credit was established under EPAct 2005 to provide a \$1.00 per gallon tax credit for producers of renewable diesel. Renewable diesel is produced through a method that differs from biodiesel, making it ineligible for the biodiesel tax credit. The credit expired at the end of 2011.

The 2008 Farm Bill introduced the cellulosic biofuel PTC to provide a \$1.01 per gallon credit for cellulosic biofuels. This measure supports compliance with EISA production volume requirements. The credit is set to expire at the end of 2012.

The Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 established the alternative fuel excise tax credit. Under the law, producers may claim a \$0.50 per gallon credit for alternative fuel. The definition for alternative fuels does not include ethanol, methanol, biodiesel, or renewable diesel, but does include other “liquid fuel derived from biomass.”⁵⁰ The measure expired at the end of 2011.

Subsidies, Tariffs, and Programs

The Advanced Biofuel Payment Program was authorized under the 2008 Farm Bill to provide direct payments to producers of advanced biofuels. The program, administered by the USDA, provides payment for the qualified actual amount of advanced biofuels produced annually and an additional payment for certain increases in production demonstrated over time. For this program, biofuels may not

⁴⁷ See footnote 11, this chapter.

⁴⁸ EPAct, 109-58 U.S.C. §1342 (2005).

⁴⁹ Tax Relief and Healthcare Act, 109-432 U.S.C. (2006).

⁵⁰ Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act, 111-312 U.S.C. (2010).

be produced from corn kernel starch feedstocks.⁵¹ Through mandatory funding, the program received \$195 million in 2009–11 and \$65 million in 2012. It is set to expire at the end of FY12.

The Biomass Crop Assistance Program (BCAP), established by the 2008 Farm Bill, uses two mechanisms to financially assist biomass producers on designated lands for specified crop types. The producers may apply for either annual payments for eligible biomass crops under contract with USDA's Commodity Credit Corporation (CCC) or matching payments for biomass crops delivered to qualified bioenergy facilities. The eligible land types, established by the Farm Bill, are generally non-industrial private forestland that meets particular sustainable agriculture criteria; crops must be renewable biomass, with higher payments going to those that support RFS2 compliance. BCAP received \$112 million in 2011, and mandatory spending was capped at \$17 million in 2012. The program is scheduled to expire at the end of 2012.

Congress established a tariff on imported ethanol under the Omnibus Reconciliation Act of 1980. Extended under the 2010 Jobs Act, but terminated at the end of 2011, it added a 2.5 percent ad valorem tax and a most-favored-nation duty of \$0.54 per gallon to ethanol imported into the United States for use as fuel. The effect of the tariff had been to reduce ethanol imports, a significant portion of which would have been generated from sugar-based ethanol in Brazil, which has a lower GHG impact than US corn-based ethanol. However, concurrent with the tax's expiration in 2011, a weak international sugar crop decreased Brazilian sugar-based ethanol production and increased US corn-based ethanol exports; as a result, the expiration of the tariff has not been significantly challenged by interest groups. This may change if ethanol trade balances reverse.⁵²

The impact of potential increases in US imports of Brazilian ethanol on sustainability of biofuels consumed in the United States is difficult to determine without further investigation. Sugar-based ethanol production is generally less energy intensive than corn-based processes, but the impacts of farming and transportation may vary widely depending on location and methods. These impacts may be significant, but they are beyond the current scope of this report.

The 2008 Farm Bill introduced a provision to encourage production of biofuels from surplus sugar under the Feedstock Flexibility Program for Producers of Biofuels. Each year, USDA's CCC purchases sugar that it would otherwise receive as in-kind payment for various agricultural price regulation mechanisms. This purchased sugar is resold to biofuel producers in a competitive process. The program

⁵¹ USDA, "Advanced Biofuel Payment Program," *Rural Development*, www.rurdev.usda.gov/BCP_Biofuels.html.

⁵² Environmental Finance, "Brazil Look to Benefit from US Renewable Fuel Standard Mandates," *Oilprice.com*, oilprice.com/Alternative-Energy/Biofuels/Brazil-Look-to-Benefit-from-US-Renewable-Fuel-Standard-Mandates.html.

is designed to ensure that it operates at no net cost to the government, while utilizing sugar that would otherwise be moved to government stocks.⁵³

EPAct 2005 established DOE's Cellulosic Ethanol Reserve Auction. The mechanism encourages and accelerates commercialization of the first billion gallons in annual cellulosic biofuel production by 2015. Under the program, potential producers of cellulosic ethanol submit bids for production incentives. At least the four lowest bids placed by eligible parties receive the subsidy. Corresponding to the EISA definition of "cellulosic biofuels," eligible fuels must be at least 60 percent less GHG intensive than the baseline.⁵⁴

In addition to direct subsidies called for in the 2008 Farm Bill, it requires USDA to perform a range of studies to facilitate the dissemination of information to the public and agriculture industry. It contains a provision to develop a database of best practices regarding the potential to produce a range of biomass crops and methods for managing them throughout the production and logistics chain.⁵⁵ In addition, the bill calls for studies of how insurance policies might be specifically designed to protect dedicated energy crops.⁵⁶

A number of the subsidies discussed in this subsection have either recently expired or are set to expire in the near future. One study estimates that federal spending on clean energy will drop by 75 percent in 2009–14 if such subsidies are not extended. The study goes on to note, however, that where subsidies are ineffectively applied, their expiration could lead to policymaking that ultimately strengthens the viability of the renewable market.⁵⁷

Renewable Identification Numbers

Under RFS2, EPA ruled that producers or importers of certified biofuel pathways (including jet fuel) register and generate RINs. Devised to enable "obligated party" fuel producer compliance with RFS2 production mandates, RINs can be separated once blended and sold to fuel producers (that didn't produce enough biofuel to meet their obligation) so they can meet their mandated production requirements.⁵⁸ RINs are 38-digit codes, but their value comes from the RIN marketplace, particularly when volumetric mandates are falling short by fuel type, such as in advanced biofuels.⁵⁹ Their value differs by fuel category and multiple

⁵³ USDA, "Feedstock Flexibility Program," *Farm Service Agency*, www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=ffpb.

⁵⁴ EPA, "Production Incentives for Cellulosic Biofuels; Reverse Auction Procedures and Standards," *Federal Register Environmental Documents*, www.epa.gov/fedrgstr/EPA-IMPACT/2009/October/Day-15/i24778.htm.

⁵⁵ FCEA, 110-246 U.S.C. §1672c (2008).

⁵⁶ FCEA, 110-246 U.S.C. §12023 (2008).

⁵⁷ Mark Muro, "Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence," *Brookings*, www.brookings.edu/research/papers/2012/04/18-clean-investments-muro.

⁵⁸ Lihong McPhail et al., *The Renewable Identification Number System and U.S. Biofuel Mandates*, BIO-03 (Washington, DC: USDA, November 2011).

⁵⁹ Ibid.

factors, including market speculation and demand, conventional crude price, and the aforementioned tax credits.⁶⁰

Environmental Sustainability

In this subsection, we focus on environmental sustainability and its statutory and policy relevance in the context of biofuels. For our purposes, the key functional criteria that characterize the environment sustainability pillar are as follows:

- ◆ Air
- ◆ Water
- ◆ Land use
- ◆ Soil
- ◆ Productivity
- ◆ Waste
- ◆ Biological resources.

Table 3-6 shows the biofuel-related statutes and policy relevant to the criteria of the environmental sustainability pillar.

Table 3-6. Environmental Pillar Relevant Statutes and Policies

Criteria	Statute	Policy
Air	BRDA 2000, Sections 302 and 307 Farm 2002, Section 9009 EPA 2005, Sections 941 and 1601 EISA 2007, Section 526 FCEA 2008, Section 9008 NEPA 1970, Section 102 CAA 1990, Sections 109, 111, 112, 118, 202, 231, 241, and 502 and Title VI. EPCRA, Section 304	EO13423 EO13423, Sections 2 and 3 EO 13514, Sections 1, 2, 9 and 13 OMB Scorecard
Water	BRDA 2000, Section 307 Farm 2002, Section 9002 EPA 2005, Sections 101 and 941 EISA 2007, Sections 202, 204 and 232 FCEA 2008, Section 9008 NEPA 1970, Section 102 CWA, Sections 1313, 1342, and 1321 EPCRA, Section 304	EO13423, Section 2 EO 13514, Sections 1 and 2 OMB Scorecard

⁶⁰ Ibid.

Table 3-6. Environmental Pillar Relevant Statutes and Policies

Criteria	Statute	Policy
Land use	BRDA 2000, Sections 304 and 307 Farm 2002, Section 9009 EISA 2007, Section 201 NEPA 1970, Section 102	EO 13514, Sections 2, 8, and 9
Soil	BRDA 2000, Section 302 Farm 2002, Section 9002 EPA 2005, Section 941 EISA 2007, Sections 204 and 232 FCEA 2008, Section 9008, NEPA 1970, Section 102	
Productivity	BRDA 2000, Section 307 EISA 2007, Sections 202, 204 and 232 NEPA 1970, Section 102	
Waste	BRDA 2000, Section 307 Farm 2002, Section 9002 EISA 2007, Section 204 FCEA 2008, Section 9008 NEPA 1970, Section 102 CWA, Section 1345	EO13423, Sections 2 and 3 EO 13514, Sections 1 and 2
Biological resources	BRDA 2000, Sections 306 and 307 EISA 2007, Sections 201, 202, and 204 NEPA 1970, Section 102	

Note: EPCRA = Emergency Planning and Community Right to Know Act and CWA = Clean Water Act.

Of the sustainability pillars covered in this report, environmental sustainability is the one most directly addressed by both biofuel- and criteria-focused policy. To start, federal, state, and local laws and regulations cover biofuel feedstock, transportation, conversion, production, and use. These regulations establish regulatory and media thresholds designed to protect air, water, land, soil, and biological resources. In general, these regulations aim to ensure that adverse environmental impacts related to business and individual activities are limited to acceptable levels. By establishing minimum standards, they inform and even serve as baseline biofuel sustainability metrics. In the following subsections, we discuss the most relevant policies and statutes that touch on the various criteria associated with environmental sustainability.

AIR

The CAA is the federal law of the land mandating the protection and improvement of our nation's air quality and the stratospheric ozone layer. The CAA authorizes EPA to pass regulations, enforce standards, and support initiatives improving air quality in the United States. State and tribal governments have delegated authority to monitor air quality, issue permits, and inspect facilities under

their jurisdictions. States with delegated authority are required to develop state implementation plans (SIPs) summarizing their plans to control air pollution under the CAA and their state statutes and regulations, respectively. SIPs and their associated state statutes provide the framework for air permits that may be necessary when siting new feedstock conversion or biorefinery facilities.

Air Quality

The CAA sets minimum ambient air quality standards for the nation and calls for the regulation of “criteria pollutants” in geographic locations, where air quality is considered harmful to public health and the environment, known as non-attainment areas. In these areas, significant sources of criteria pollutants cannot be operated without permits and certain mitigation actions. CAA requirements may apply to biofuels during their production and use phases. For example, particulates generated by grain elevators could contribute to air pollution under particulate matter (PM) 2.5 or PM10.⁶¹ Also, vegetable oil processing and conversion methods may utilize or produce volatile organic compounds, subject to National Emission Standards for Hazardous Air Pollutants (NESHAPS). Biofuel producers may be required to obtain a permit and install control measures, such as condensers, scrubbers, or process flares. Use of Title VI ozone depleting substances (ODS) in the biofuel supply chain may not only pose a regulatory liability but also a critical material obsolescence hazard.

Biofuel use and combustion result in air emissions and pollutants. However, in some instances, drop-in biofuels may release smaller amounts of pollutants than fossil fuels, so their use can serve as a mitigation action in non-attainment areas. For example, conventional diesel fuels may be replaced with renewable diesels to take advantage of the lower sulfur content, which helps to reduce particulate matter emissions.

Greenhouse Gases

Section 526 of EISA 2007 prohibits any federal agency from purchasing of petroleum products derived from unconventional or alternative fuel sources with life-cycle GHG emissions exceeding those of conventional crude oil.⁶² One effect of this stipulation is to prevent the federal government from purchasing fuels derived from carbon-intensive, unconventional sources, such as coal.

Section 526 establishes baseline sustainability metrics for renewable fuels in the form of threshold limits on life-cycle GHG emissions to conventional petroleum products based on a 2005 baseline. DLA Energy analyses based on EPA findings characterize neat renewable-based ethanol and biodiesel as having life-cycle GHG

⁶¹ PM2.5 are 2.5 micrometers or less in size; PM10 are from 2.5 to 10 micrometers. The smaller particles are generally more dangerous.

⁶² See footnote 12, this chapter.

emissions below those of conventional gasoline and diesel.⁶³ All blends of ethanol and biodiesel with conventional gasoline and diesel meet the Section 526 threshold requirements.

However, as alternative fuels evolve to meet new requirements, such as drop-in aviation and marine fuels, Section 526 requirements must be considered. In particular, fuels produced by unconventional means, such as F-T derived jet fuels using GHG-intensive processes may not meet life-cycle GHG thresholds. When such pathways are hybridized with biomass feedstock, the resulting aggregate life-cycle GHG emissions may or may not exceed the Section 526 threshold of the 2005 petroleum baseline.

RFS2 went further, creating four subcategories of renewable fuels, each with its own volumetric requirement and GHG reduction threshold. The GHG thresholds require life-cycle emissions to be less than those of the same 2005 baseline for conventional petroleum fuels being replaced. Table 3-7 highlights the GHG reduction thresholds and fuels EPA has determined meet them.

Table 3-7. RFS2 GHG Reductions by Fuel Type

Fuel category	Minimum reduction from 2005 baseline (%)	Compliant fuels ^a
Renewable fuel ^b	20	<ul style="list-style-type: none"> ◆ Ethanol produced from corn starch at a new natural gas, biomass, or biogas fired facility using advanced technologies ◆ Biobutanol from corn starch
Advanced biofuel	50	<ul style="list-style-type: none"> ◆ Ethanol from sugarcane
Biomass-based diesel	50	<ul style="list-style-type: none"> ◆ Biodiesel and renewable diesel from soy oil or waste oils, fats, and greases ◆ Biodiesel and renewable diesel produced from algal oils
Cellulosic biofuel	60	<ul style="list-style-type: none"> ◆ Ethanol and cellulosic diesel

Source: 40 CFR 80.1401 (see footnote 32, this chapter).

^a EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels," EPA OTAQ, EPA-420-F-10-006, February 2010; www.epa.gov/otaq/renewablefuels/420f10006.pdf

^b The 20% criterion generally applies to the renewable fuel from new facilities that commenced construction after December 19, 2007.

GHG thresholds for covered fuels are a significant sustainability metric that now applies to the biofuel industry. RFS2 lists common production processes that meet the requirements, but signals EPA's recognition that the industry and technologies are evolving by establishing procedures that allow reporting entities to request approval for unlisted processes. In March 2012, in response to objections from

⁶³ EPA, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006 (Washington, DC: February 2010), www.epa.gov/oms/renewablefuels/420r10006.pdf.

environmental groups, EPA withdrew a proposal to categorically approve fuels derived from camelina oil, energy cane, giant reed, and napiergrass and certain new production processes as being compliant.⁶⁴ Opponents successfully argued that the associated land use impacts of these feedstocks and processes may negatively impact the biofuels' sustainability. As a result, EPA will continue to approve new feedstocks and processes individually after additional review.

While this draws a quantitative line in the sand, the protocols for calculating life-cycle emissions continue to mature, such that biofuels or blends may no longer meet Section 526 thresholds. EPA methods for calculating life-cycle emissions are updated with regulatory requirements and advances in methods. As the science and practice move forward, consideration is warranted on how such changes could impact the life-cycle GHG estimates and the implications for biofuel procurements in the future. This is even more applicable when consequential impact analysis is applied, particularly within the international contents.

The European Union (EU) Emissions Trading System (ETS) is a GHG cap-and-trade system begun in 2005, covering EU member states in addition to Norway, Iceland, and Liechtenstein.⁶⁵ Originally, the ETS covered only emissions from large emission sources, such as power production facilities located in the EU. Beginning in 2012, the system started including carbon dioxide (CO₂) emissions from the aviation sector, including international carriers landing in or departing from EU member states.⁶⁶ Military flights are exempt from this requirement.

However, airline carriers around the world are now increasing efforts to replace conventional aviation fuels with biofuels due to landing tariffs that came into effect on January 1, 2012. The ETS emissions calculations assume that biofuels derived from biomass feedstocks have an emission factor equal to zero, thus not affecting the emissions cap. As a result, Airlines for America (A4A) and the commercial aviation carriers in the United States are keenly looking at drop-in biofuel pathways and production initiatives.

WATER

Water resources are needed or impacted across the entire life-cycle of most or all biofuel pathways under consideration. Large quantities of water may be required during the growth and processing of biomass feedstocks and fuel production. Agricultural or silvicultural activities may also result in erosion and runoff, introducing silt and excess fertilizer into natural waterways and aquifers, which impact water quality. Feedstock conversion and biorefinery operations could generate discharges from the production processes, creating additional water quality

⁶⁴ See footnote 15, this chapter.

⁶⁵ DOE and Climate Change, "EU Emissions Trading System (EU ETS)," *Department of Energy & Climate Change*, www.decc.gov.uk/en/content/cms/emissions/eu_ets/eu_ets.aspx.

⁶⁶ Under current law, US airlines will be required to remit payment for emissions that exceed their allotted credits in 2013. However, US and international lawmakers are in the process of contesting the requirements, which may result in modification or elimination of the requirements.

concerns and compliance requirements. Almost all biofuel- or sustainability-oriented statutes and policies cite the need to protect water quality and minimize use of water resources.

The CWA of 1990 is the most directly relevant federal statute for this criteria as it regulates the discharges of pollutants into waters from indirect sources, such as agricultural storm water runoff, as well as direct sources, such as biorefinery outflows. CWA regulations include quality standards for surface waters and requirements for protecting wetlands. The CWA authorizes the National Pollutant Discharge Elimination System (NPDES) permitting system.

The Safe Drinking Water Act (SDWA) of 1974 ensures the quality of drinking water to protect public health. SDWA regulations primarily focus on public water systems and compliance with health standards. In terms of biofuel pathways, they have potential relevance as they also focus on the protection of underground sources of drinking water.

EPAct 2005, EO 13423, EISA, and EO 13514 all cite the importance of water resources and the imperative for efficient use and stewardship. Water resources are needed at numerous points during the biofuel life-cycle. Large volumes may be required during the growth and processing of biomass feedstocks and during fuel production.

Water laws vary by state, but biofuel pathways that require significant water resources may face challenges in states with water rights limitations or absolute limitations due to drought and climate, as illustrated in the 2012 nationwide drought. Certain geographic locations with limited water availability may, as a result, have more stringent rules that limit water access. Consequently, such operating constraints and compliance costs may be sufficient to dictate siting decisions. However, these regulations also influence the development of crops, technologies, and processes that require less water or fertilizer, or reduce contaminated discharges. Such advances can expand siting options, reduce compliance costs, and improve biofuel sustainability.

LAND USE AND SOIL QUALITY

The primary land use and soil quality impacts associated biofuels come during the feedstock production and fuel processing facility construction stages of the supply chain. As with all crops, expansion of biofuel feedstock production to fulfill increasing demand can result in conversion of existing land type to bioenergy crop uses. While the EISA definition of renewable biomass minimizes potential conversion of natural areas and federal forests, land use conversion could result in different rates of erosion, changes to carbon-absorbing plant cover, increased runoff, animal habitat alteration, and pollutant deposition from pesticides and farm equipment use. Feedstocks integrated within existing agricultural and forestry management systems may have a lesser degree of land use conversion but will still need to consider changes in soil erosion and pollution.

RFS2 aims to reduce such impacts by stipulating the use of particular land types to meet volumetric requirements (Table 3-1). It encourages the use of underutilized or marginal lands, crops with high energy content per growing area (see “Productivity”), and farming waste and byproducts. NEPA, though not designed specifically for biofuel production, requires environmental impact assessments for certain federal and federally supported projects to ensure that potential land and soil impacts, among other environmental considerations, are minimized during construction and operation.

PRODUCTIVITY

Productivity refers to the conversion efficiency of the various activities along the biofuel production path. During the feedstock production phase, productivity depends on multiple factors, such as siting operations where environmental conditions are appropriate, and optimizing the application of fertilizers and pesticides. Long-term crop productivity depends in part on employing harvest schedules that yield the most biomass with the least amount of resource inputs or depletion. Fuel processing efficiency requires the effective use of feedstocks and conversion technologies that produce fuels with high energy content with minimal energy and material input. RFS2 specifically encourages productivity improvements through a range of measures, such as use of waste materials, marginal lands, and advanced cellulosic conversion technologies.

WASTE

Feedstock cultivation, pre-processing, and biofuel production all inherently involve the generation of co-products, solid waste, hazardous waste, and wastewater. Pesticides and fertilizer production and use produce chemical byproducts and excess materials requiring management and disposal. Farm activities result in crop residues (when not the feedstock themselves) and other waste materials coming from the operation of farming equipment. During biofuel production, a range of chemicals may be used to extract intermediate products or catalyze synthesis reactions, all of which must be managed to minimize impacts on human health and the environment.

Laws and regulations—familiar to all farming and fuel processing operations—are already in place to address these issues. The Toxic Substance Control Act (TSCA) of 1976 establishes requirements for the production, importation, use, and disposal of chemical substances to protect human health and safety. The Resource Conservation and Recovery Act (RCRA) of 1976 regulates wastes from “cradle to grave,” including the generation, transportation, treatment, storage, and disposal; RCRA also sets forth a framework for the management of non-hazardous solid wastes and underground tanks containing petroleum and other hazardous substances. The EPCRA of 1986 requires the inventory and reporting of chemicals stored at certain facilities and annual reporting of toxic chemical releases to help local communities protect public health, safety, and the environ-

ment from chemical hazards. The Oil Pollution Act (OPA) of 1990 requires oil storage plans detailing spill response procedures.

In addition to these regulations aimed at limiting the potential impact of releases of waste materials, RFS2 encourages the use of byproducts and waste materials, such as waste oils and crop residues, in the production biofuels, thus eliminating the need to dispose of waste.

BIOLOGICAL RESOURCES

Feedstock and biofuel production activities can have siting, construction, and operational impacts that require consideration of threatened or endangered species. The federal government has enacted a variety of laws and regulations designed to protect vulnerable species in the natural environment. The Endangered Species Act (ESA) of 1973 and Marine Mammal Protection Act (MMPA) of 1972 are two of the most notable laws that seek to protect vulnerable species. These laws may require such actions as siting assessments or special management of pesticides when critical habitat may be involved. When government funds or partners are involved, NEPA review and consideration of biological resources may apply, a requirement that can significantly affect cost and schedule, particularly in the case of biorefinery plant siting and construction.

Social Sustainability Criteria

In this subsection, we discuss the implication of the relevant statutes and policies on biofuels and their social sustainability. For our purposes, the key functional criteria that characterize the social sustainability pillar include:

- ◆ Food security
- ◆ Quality of life
- ◆ Safety and health
- ◆ Participation.

Table 3-8 lists the statutes and policies generally or specifically relevant to both biofuels and social sustainability.

Table 3-8. Social Pillar Relevant Statutes and Policies

Criteria	Statute	Policy
Food security	EISA 2007, Section 202 FCEA 2008, Section 9008	
Quality of life	BRDA 2000, Sections 302 and 307 Farm 2002, Section 9002 EPAAct 2005, Section 941 EISA 2007, Section 202 FCEA 2008, Section 9008	
Safety and health	Farm 2002, Section 9002 EPAAct 2005, Section 941 NEPA 1970, Section 102 CWA EPCRA, Sections 302; 304; 312; 313	
Participation	EISA 2007, Sections 202 NEPA 1970, Section 102	EO 13514, Sections 1 and 16

Many of the statutes and policies cite social sustainability criteria as primary ends in developing and expanding a US biofuel industry. While food security and safety and health are mentioned, job creation and rural development are the stated purposes and squarely equate to quality-of-life outcomes. Participation is often cited, but it is a basic tenet required under NEPA and affirmed in EO 13514.

FOOD SECURITY

Food security as it relates to biofuels deals primarily with concerns over competition for crops that can be used as both food and biofuel feedstocks, such as corn, soybeans and sugar. In addition, even when nonfood crops are used as feedstocks, competition for cropland may arise as arable land is finite. When these conflicting priorities persist, food prices may escalate, creating particular hardships for lower-income consumers for whom a large portion of income may go toward food. Statutes and policies that support first generation biofuels, which largely utilize food crops as feedstocks, arguably exacerbate food insecurity.⁶⁷ In contrast, statutes and policies that encourage nonfood crops, waste agricultural materials, and the use of marginal farming land for feedstock production also aim to address food security concerns.

Both EISA and the 2008 FCEA contain measures to address food security concerns. RFS2, under EISA, requires that by 2022, at least 58 percent of the 36-billion-gallon biofuel mandate be advanced biofuels (those from nonfood sources).⁶⁸ FCEA established a \$1.01-per-gallon tax credit for cellulosic biofuel

⁶⁷ Ronald Trostle et al., *Why Have Food Commodity Prices Risen Again?*, WRS-1103 (Washington, DC: USDA, June 2011).

⁶⁸ See Figure 3-2.

production, which encourages the transition to non-food crops for biofuel feed stocks.

QUALITY OF LIFE

Quality of life is a component of social sustainability that overlaps significantly with food security, safety and health, and participation in economic activity as they relate to biofuels. Statutes and policies highlighted throughout this chapter that address food availability, pollution and GHG risks, and employment inherently address quality-of-life issues. In particular, EISA and FCEA address food security, the statutes discussed under the environmental pillar address environmental concerns, and the various farm bills encourage the expansion of small and rural businesses and the associated jobs it spurs.

SAFETY AND HEALTH

Fuel combustion introduces safety and health concerns because of the associated emissions of criteria air pollutants, such as particulate matter, and hazardous materials. Workers at farming and biofuel production facilities can be exposed to a range of hazards related to the use of mechanical equipment and process-related chemicals. Occupational Safety and Health Administration (OSHA) and EPCRA regulations may apply and require consideration in terms of compliance but also opportunities to minimize such costs by proactive application of established pollution prevention and design for environment efforts.

More broadly, biofuel production and use will generate some particulate and other pollutant emissions that could pose respiratory health hazards for the general population. Environmental statutes discussed under the environmental pillar—such as the CAA, CWA, RCRA, EPCRA, and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)—address health concerns for the general public by controlling pollutant releases. Other statutes and policies that aim to expand the use of biofuels, such as EISA, encourage the displacement of conventional fossil fuels, which are often more harmful to public health than biofuels.

PARTICIPATION

Expansion of the biofuel industry can contribute to individuals' participation in economic and employment opportunities and open new production facilities in communities not historically involved in conventional fuel production. Various statutes and policies are specifically designed to support small and rural biofuel businesses, thus aiming to open up opportunities for employees, cooperatives, and communities to participate in the development of these new business endeavors.

At the federal level, participation often refers to public involvement in government, economic, and community activities. Both NEPA and EO 13514 directly introduce measures that help enable transparency in government and encourage citizens to participate in decision making. Beyond these direct mechanisms,

several indirect efforts contain engagement or comment mechanisms detailed in the operational, economic, and environmental sustainability pillars. For example, economic incentives and tax breaks, such as those under the small ethanol producer PTC, engage and support the development of small farmers' production capacity, which increases the opportunity to participate economically. For brevity, we do not repeat such policies and statutes here.

POLICY IMPLICATIONS ON FEDERAL AGENCY ROLES

As demonstrated, federal policies affects all sustainability pillars. They not only emphasize the importance of these distinct criteria, but in many cases they specifically prescribe their application through regulation. They also promote the authorization and funding of executive branch agency programs. Chapter 4 moves past the regulatory implications to introduce the agency programs and their contributions to biofuel sustainability.

Chapter 4

Federal Biofuel Roles and Public-Private Efforts

In Chapter 3, we considered sustainability, energy security, and biofuel policy and its implications by pillar and criteria. These statutory authorities, authorization, and policies have shaped more than a decade of interagency biofuel programs, initiatives, and efforts. Recent efforts to investigate, develop, and produce drop-in, advanced biofuels have piqued the interest of non-traditional users, such as the military services and commercial aviation. With this interest comes an appreciation for the sustainability challenges raised with first generation biofuels and resultant efforts to understand advanced biofuel upstream sustainability benefits, concerns, and knowledge gaps. However, gaining this understanding requires a broad cross-section of expertise, data, and tools that call for an interagency endeavor. In this chapter, we describe the federal agencies, programs, initiatives, and roles relevant to advanced biofuel sustainability. We also discuss select public-private and industry efforts focused on fostering commercial-scale production of drop-in biofuels and their sustainability. Finally, we identify and briefly introduce some relevant bioenergy sustainability standards we considered as part of this study.

INTERAGENCY AND AGENCY ROLES

For more than a decade, Congress has mandated that the executive branch to explore the potential of bioenergy and expand its production and use across the country. While this study primarily focuses on advanced biofuels, understanding the diverse interagency and departmental roles related to biofuels writ large is useful in navigating the federal biofuel landscape. Moreover, this awareness provides the context for mapping federal collaborators and partner capabilities, their connections, and potential contributions to better assessing, maturing, and achieving biofuel supply chain sustainability.

Office of Science and Technology Policy

The White House Office of Science and Technology Policy (OSTP) advises the Executive Office of the President on the consequences of science and technology as it relates to both domestic and international affairs. OSTP's mission is first

to provide the President and his senior staff with accurate, relevant, and timely scientific and technical advice on all matters of consequence; second, to ensure that the policies of the Executive Branch are informed by sound science; and third, to ensure that the scientific and technical work

of the Executive Branch is properly coordinated so as to provide the greatest benefit to society.¹

OSTP focuses on four main areas: science, technology, environment and energy, and national security and international affairs. Its Technology Division has committed to advancing comprehensive technologies, including the “development of new clean energy sources.”²

BIOFUEL ROLES

The White House’s *Blueprint for a Secure Energy Future* provides the current executive branch vision for US energy policy, laying out focus areas seeking to advance biofuel technology and touch on sustainability priorities:

- ◆ *Reduce oil use with bioenergy.* GBEP will soon begin an initiative in West Africa to promote the switch from traditional biomass use to more sustainable and modern bioenergy that can better offer energy access and food security.
- ◆ *Invest in DOE’s Advanced Research Project Agency–Energy (ARPA-E).* Support projects that industry by itself cannot or will not support due to the risk involved. Success in these technologies will reduce imported energy, reduce energy-related emissions, including GHGs, and improve energy efficiency.³
- ◆ *Coordinate both R&D investments and clean energy technology deployment.* Clean energy R&D priorities increasingly emphasize solar, geothermal, offshore wind, and advanced biofuels, aligning with policies that focus on the deployment of these technologies.
- ◆ *Invest in clean energy R&D utilizing the Recovery Act.* The administration has invested in efforts targeted at the demonstration of clean energy projects.
- ◆ *Commercialize new technologies.* Scale cellulosic and advanced biofuels technologies by opening a minimum of four commercial-scale cellulosic or advanced biorefineries. To encourage this shift, the President has asked the secretaries of Agriculture, Energy, and the Navy to find a solution that speeds up the process of finding drop-in biofuel alternatives for diesel and jet fuel.

¹ US White House, “About OSTP,” *Office of Science and Technology Policy*, www.whitehouse.gov/administration/eop/ostp/about.

² Ibid.

³ DOE, “DOE Launches the Advanced Research Projects Agency-Energy, or ARPA-E,” *Energy Efficiency & Renewable Energy News*, apps1.eere.energy.gov/news/news_detail.cfm/news_id=12478.

SUSTAINABILITY RELEVANCE

These five thrust areas are directly relevant to advancing biofuels and span the entire spectrum of sustainability pillars. The energy security (petroleum reduction and energy access) and availability (demonstration and commercialization of advanced biofuels) activities directly support operational sustainability. Biorefinery commercialization efforts accelerate the economic viability of advanced drop-in fuels. The clean technology efforts aim at environmental criteria, such as air and GHG emissions. GBEP focuses on social pillar criteria, including food security.

Biomass Research and Development

The Biomass R&D Act of 2000, as amended in the FCEA of 2008, aims “to coordinate R&D activities relating to biobased industrial products (A) between USDA and DOE; (B) and with other departments and agencies of the federal government.” Together they established the Biomass Research and Development (BRD) Board, Technical Advisory Committee (TAC), and annual initiative solicitations

BRD BOARD

The board’s main function is to coordinate BRD activities among federal agencies to maximize federal programs and bring harmonization to federal strategic planning.⁴ The board is co-chaired by senior DOE and USDA officials and has representatives from OSTP, DOE, USDA, Treasury, DOT, DoD, EPA, the Departments of the Interior and Commerce, the National Science Foundation (NSF), and the Office of the Federal Environmental Executive. The NSF, Department of the Interior and DoD seats are currently vacant.⁵

In October 2008, the board published the *National Biofuels Action Plan* (NBAP), which describes areas where interagency cooperation would best help biofuels technologies move from “promising ideas to competitive solutions.” The NBAP highlights action areas and sets the next steps and actions that the board will take. The board has also commissioned interagency working groups and directed them to develop reports, plans, and other products aimed at better coordinating federal interagency efforts as well as identifying specific barriers to commercialization across the biofuel supply chain. Formed around this framework are sustainability, feedstock production, feedstock logistics, conversion science and technology, distribution infrastructure, and environment health and safety working groups.

⁴ BRD, “Board,” *BR&D*, www.usbiomassboard.gov/board/board.html.

⁵ BRD, “Board Members,” *BR&D*, www.usbiomassboard.gov/board/members.html.

Since 2008, new working groups have been formed, and the current working groups focus on five areas:

1. *Feedstocks*. This group considers the R&D needs of next-generation bio-fuels at the scale of feedstock development and production or supply while looking to conserve natural resources.
2. *Logistics and distribution*. This group looks to overcome technical challenges to systems integration, scalability, and deployability evaluates storage and transportation options, logistics, fuel distribution, and end-use requirements.
3. *Conversion*. This group identifies R&D needs to improve or optimize execution of biomass conversion technologies and encourage commercialization.
4. *Algae*. This group facilitates coordination of federal research, development, demonstration, and deployment activities relating to the production and use of algae as a biofuel.
5. *Supporting activities*. This group considers additional activities such as anthropogenic modification of the biological carbon cycle and environmental and human health impacts.

TAC

The TAC, established by the Biomass R&D Act, comprises 30 to 40 volunteers from industry, academia, nonprofits, and local government. Official TAC functions include

- ◆ advising the Secretary of Energy, the Secretary of Agriculture, and others concerning the technical focus of requests for proposals issued under the Biomass R&D Initiative, and designing proposal evaluation criteria;
- ◆ facilitating discussions, affiliations, and collaboration among federal and state agencies, agricultural producers, industry, and other stakeholders interested in the program's activities; and
- ◆ evaluating and performing strategic planning on program activities relating to the initiative.⁶

TAC is an independent body that advises agencies regarding the technical focus and direction of the initiative.

⁶ BRD, "Committee," *BR&D*, www.usbiomassboard.gov/committee/committee.html.

BIOMASS R&D INITIATIVE

The initiative awards funds to address technical areas related to biomass. It derives its authority from the FCEA of 2008 and EPCA of 2005. All projects that receive funding fall into one of the following three categories:

- ◆ Feedstocks development—focused primarily on feedstock demonstrations
- ◆ Biofuels and biobased products development
- ◆ Biofuels development analysis.

SUSTAINABILITY RELEVANCE

The BRD Board previously commissioned a sustainability interagency working group in accordance with NBAP. Of the resources publically available, the working group produces two reports our study team found helpful in understanding biofuel sustainability and its implications:

- ◆ *Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research Biofuels Development Analysis*, 2008
- ◆ *Sustainable and Adequate Biofuels Feedstock Production: Recommendations for Federal Research and Development*, 2011

These reports provide a solid, peer review foundation for defining feedstock sustainability, propose some environmental criteria areas, and discuss indicators and even certification approaches. Despite the comprehensive lens elaborated, the analysis and modeling approach often focus back on feedstock production analyses and offer little on decision support for end users. These products do, however, provide good coverage of biomass and biofuel R&D gaps and needs.

The sustainability interagency working group is no longer active, but the current supporting activities working group does focus on many of the same areas. More specific sustainability R&D gaps are being explored through grants, but discussions with federal stakeholders seem to suggest that a lack of a sustainability vision and coordination entity tasked with facilitating meaningful progress in establishing sustainability framework, assessment aids, or consistent metrics.

NSF

NSF's mission is "[t]o promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense (NSF Act of 1950)."⁷ NSF does not hire researchers or operate its own

⁷ NSF, "National Science Foundation Investing in America's Future: Strategic Plan FY 2006–2011," *Publications*, www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf0648.

laboratories, instead supporting scientists, engineers, and educators directly through institutions such as universities and colleges.⁸ It provides competitive awards to researchers who focus on innovative research programs in science and technology that also contain provisions for educational advances.

NSF is organized into seven directorates, each of which supports science and engineering research and education: Biological Sciences; Computer and Information Science and Engineering; Engineering; Geosciences; Mathematics and Physical Sciences; Social, Behavioral and Economic Sciences; and Education and Human Resources.

BIOFUEL ROLES

NSF Engineering Directorate programs—particularly those in the Chemical, Bioengineering, Environmental and Transport Systems Division (CBET)—have awarded funds for biofuels, biopower, and bioproducts activities to individual investigators at universities, centers at multiple universities, and industrial/university collaborations. Residing in CBET is the Environmental Engineering and Sustainability cluster.

SUSTAINABILITY RELEVANCE

Funded as part of this activity, the Energy for Sustainability Program supports research and education to explore and enable potential processes for the sustainable production of electricity and transportation fuels. Its four sustainable energy technologies areas include:

- ◆ Biomass conversion, biofuels, and bioenergy
- ◆ Photovoltaic solar energy
- ◆ Wind energy
- ◆ Advanced batteries for transportation.

According to NSF, methods developed for sustainable energy production are required to be “environmentally benign, reduce greenhouse gas production, and utilize renewable resources.”⁹

⁸ NSF, “What We Do,” *About*, www.nsf.gov/about/what.jsp.

⁹ NSF, “Energy for Sustainability,” *Funding*, www.nsf.gov/funding/pgm_summ.jsp?pims_id=501026.

USDA

USDA is one the primary sponsors of biofuel R&D, and many of its authorities comes from the 2008 Farm Bill, which provided more than \$1 billion in mandatory funding over 5 years to support the energy portion of the bill focusing on the development and deployment of bioenergy and biofuels.¹⁰

BIOFUEL ROLES

USDA supports research, development, and implementation of biomass resources for renewable power, fuels, and biobased products through programs in the following:

- ◆ *Research and education.* USDA provides guidance supporting the sustainable production of biofuels and bio-based products and engaging a variety of partners, including federal, state, and local agencies, higher learning institutions, non-governmental organizations, and private industry. The Research, Education and Economics (REE)/Agricultural Research Service (ARS) and Natural Resources and Environment (NRE)/Forest Service lead this effort through USDA's Regional Biomass Research Centers.
- ◆ *Feedstock development and production.* USDA REE, Forest Service, and Natural Resources Conservation Service (NRCS) are working to develop new crops for conversion into second and third generation biofuels. Furthermore, the BCAP, run by the Farm Service Agency, awards funds to renewable crop growers and landowners that cultivate and collect biomass from their property for the purpose of biofuel production.
- ◆ *Feedstock conversion and commercialization.* USDA's Biomass Research Centers have several research objectives, including to "increase biomass production efficiency to increase grower profits and reduce biorefinery transaction costs."¹¹ These research centers invest time and resources to "address the uncertainties of expanded production up-front to avoid negative impacts on existing markets and ecosystem services." USDA provides grants and loans for feedstock conversion and commercialization through the following programs:
 - Biorefinery Assistance Program,
 - Repowering Assistance Program,
 - Bioenergy Program for Advanced Biofuels,

¹⁰ USDA, *Advancing Renewable Energy*, USDA brochure, [http://www.usda.gov/energy/maps/resources/brochure/\\$file/renewable_energy_brochure.pdf](http://www.usda.gov/energy/maps/resources/brochure/$file/renewable_energy_brochure.pdf).

¹¹ Jeffrey J. Steiner, National Program Leader, Biomass Production Systems, "USDA Biomass Research Center & ARS Contributions Background Briefing Information" (presentation, Agricultural Research Service, January 12, 2011).

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- Rural Energy for America Program, and
 - Woody Biomass Utilization Grants.

USDA supports sustainable production of biofuel because it increases America's energy security, is environmentally conscious, and supports renewable energy development.¹²

SUSTAINABILITY RELEVANCE

With its core competencies in feedstock production, USDA program data, technical, and analysis capabilities are absolutely integral to assessing and operationalizing biofuel sustainability. USDA Rural Development recently sponsored a program- and project-oriented sustainability assessment approach. USDA FAS SMEs substantially contributed to the GBEP sustainability protocol and methods. NIFA has funded R&D activities with a keen focus on agricultural and bioenergy implications. ARS is working with the Office of Naval Research on geospatially enabled analysis tools to help bioenergy feedstock producers understand their options and optimize production.

In short, USDA holds the requisite data, analysis, and programmatic resources to make any proposed biofuel sustainability architecture successful. However, it has faced challenges a common vision and aligning consistent criteria for biofuel sustainability. It is, however, a key partner¹³ in not only assessing sustainability across all pillars but in expanding bioenergy feedstock production and commercializing advanced biofuel pathways into the future.

DOE

DOE's mission "is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."¹⁴ As part of that mission, DOE is a leader in understanding and enabling the conversion of the nation's renewable and biomass resources into cost-effective, biofuels, bioproducts, and biopower. DOE funds R&D and demonstration activities to help create sustainable, cost-competitive biofuels, bioproducts, and biopower.¹⁵

¹² USDA, "Grants," *National Institute of Food and Agriculture*, www.csrees.usda.gov/fo/sustainablebioenergyafri.cfm.

¹³ The USDA Bioenergy Matrix and Energy Investments Map are useful resources to further explore and identify specific programs and bioenergy related efforts. See at: www.usda.gov/wps/portal/usda/usdahome?navid=ENERGY and www.usda.gov/energy/maps/maps/Investment.htm

¹⁴ DOE, "About Us," *Energy.gov*, energy.gov/about-us.

¹⁵ DOE, "Biomass," *Energy Efficiency & Renewable Energy*, www.eere.energy.gov/topics/biomass.html.

BIOFUEL ROLES

Within DOE, the major stakeholders in biofuels are the Office of Science, ARPA-E, and EERE Biomass Program, which are supported by teams at various DOE national laboratories, such as ORNL, ANL, NREL, PNNL, and NETL.

Office of Science

The DOE Office of Science supports scientific research for energy. It has six interdisciplinary scientific program offices: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics. Biofuel research falls under the Biological and Environmental Research program.

Under this program, the Genomic Science Program Office focuses on advancing “a new generation of research focused on achieving whole-systems understanding of biology.”¹⁶ To achieve this goal, DOE has established three Bioenergy Research Centers (BRCs) to focus on the development of

- ◆ next-generation bioenergy crops,
- ◆ discovery and design of enzymes and microbes with novel biomass-degrading capabilities, and
- ◆ transformational microbe-mediated strategies for biofuel production.¹⁷

ARPA-E

ARPA-E was created in part to fund high-risk energy technology projects that, if successful, could greatly accelerate technological advances that otherwise would not have been funded by industry. ARPA-E’s mission is to develop new energy technologies that could have highly significant implications for reduce imported energy, reduce energy-related emissions, and improve energy efficiency.¹⁸

¹⁶ DOE, “Bioenergy,” *Genomic Science Program*, genomicscience.energy.gov/biofuels/index.shtml.

¹⁷ Ibid.

¹⁸ US White House, “Fact Sheet: A Historic Commitment to Research and Education,” *Office of the Press Secretary*, www.whitehouse.gov/the_press_office/Fact-Sheet-A-Historic-Commitment-To-Research-And-Education/.

EERE

EERE's mission is to have

[a] viable, sustainable domestic biomass industry that produces renewable biofuels, bioproducts and biopower; enhances US energy security; reduces US oil dependence; provides environmental benefits (e.g., reduced greenhouse gas emissions); and creates nationwide economic opportunities.¹⁹

EERE's Office of Biomass Program (OBP) advances new bioenergy technologies from research through demonstration. This program is organized around five technical program elements:

1. *Feedstock supply*. R&D exploring technologies that use cellulosic biomass.
2. *Conversion*. R&D reducing the cost of producing cellulosic ethanol.
3. *Integrated biorefineries*. Demonstrating and deploying biomass conversion to biofuels via biochemical and thermochemical processes.
4. *Distribution infrastructure*. Demonstrating and deploying projects integrated biorefinery technologies and creating national biorefineries infrastructure.
5. *Biopower*. Facilitating the use of biomass as a feedstock for power generation.

OBP's efforts are geared toward R&D and demonstrations to ensure that biofuel is commercially feasible.

SUSTAINABILITY RELEVANCE

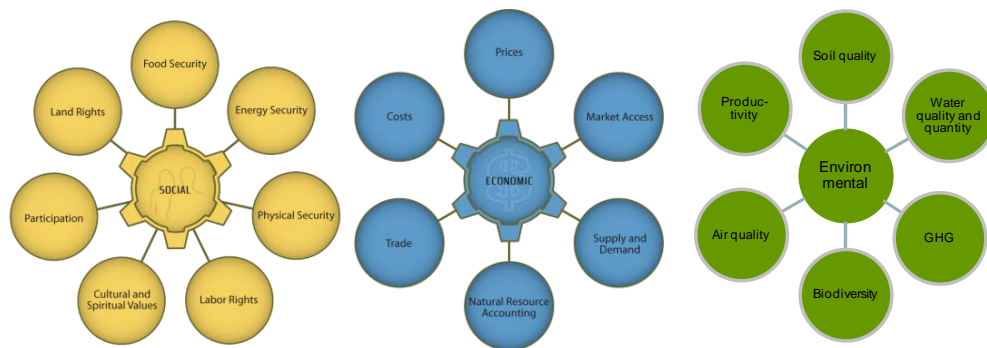
OBP focuses on three cross-cutting elements: sustainability, strategic analysis, and market expansion, each of which addresses a potential barrier to the deployment of biomass technologies.²⁰ In the sustainability area, OBP funds efforts at the national laboratories to better understand bioenergy sustainability challenges and address the potential environmental impacts of bioenergy production. The program connects with interagency and external stakeholders to identify cross-cutting areas that can be pursued to minimize environmental and social impacts across the full biofuel supply chain.

¹⁹ DOE, "About the Program," *Biomass Program*, www1.eere.energy.gov/biomass/about.html.

²⁰ DOE, "Research, Development, Demonstration, and Deployment," *Biomass Program*, www1.eere.energy.gov/biomass/research_development.html.

OBP has been collaborating with the ORNL CBES on analysis platform efforts to develop bioenergy sustainability pillar, criteria, and impact indicators framework (Figure 4-1).

Figure 4-1. ORNL Sustainability Pillars and Indicators



Source: Dale et al., *Bioenergy Sustainability: How to Define and Measure It*, ORNL, April 5, 2011.

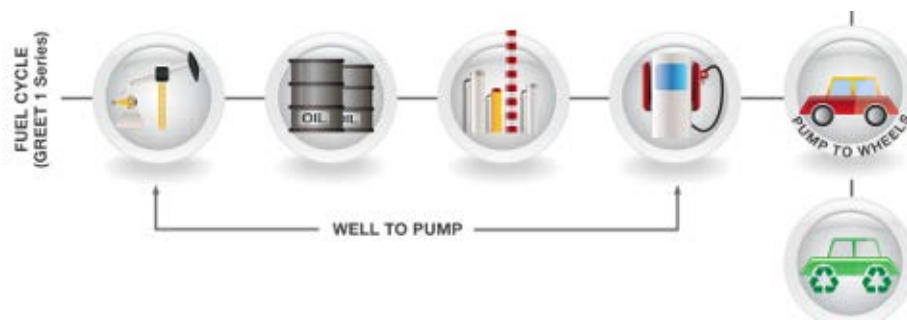
In 2011, the CBES team published its peer-reviewed suite of environmental indicators in the *Ecological Indicators* journal. It held a workshop and webinar in spring 2012, presenting the new suite of socioeconomic indicators, which are currently proceeding through peer review for publication.

While CBES is defining a suite of indicators, ANL is leading player in the development of life-cycle inventories of fuel pathways and the vehicles that consume them. Much of the ANL team's research is accessible in its Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model (GREET). First released in 1996, GREET evaluates the energy and emissions implications of transportation fuels and vehicle technologies across their life-cycle. Over the last 15 years, this attributional LCA model has expanded into one of the leading life-cycle fuel and transportation models. GREET is compiled in a "multidimensional spreadsheet model in Microsoft Excel" and available free of charge.²¹ ANL plans to update this workbook version and deploy the capability to a web-based architecture.²² GREET enables researchers and analysts to evaluate different fuel and vehicle combinations across fuel-cycle (stages 1–4) through vehicle use (stage 5). Figure 4-2 illustrates this scope.

²¹ ANL, "GREET News," *Transportation Technology R&D Center*, greet.es.anl.gov/main.

²² ANL, "GREET Workshop," *Transportation Technology R&D Center*, greet.es.anl.gov/event-workshop_dec_2011.

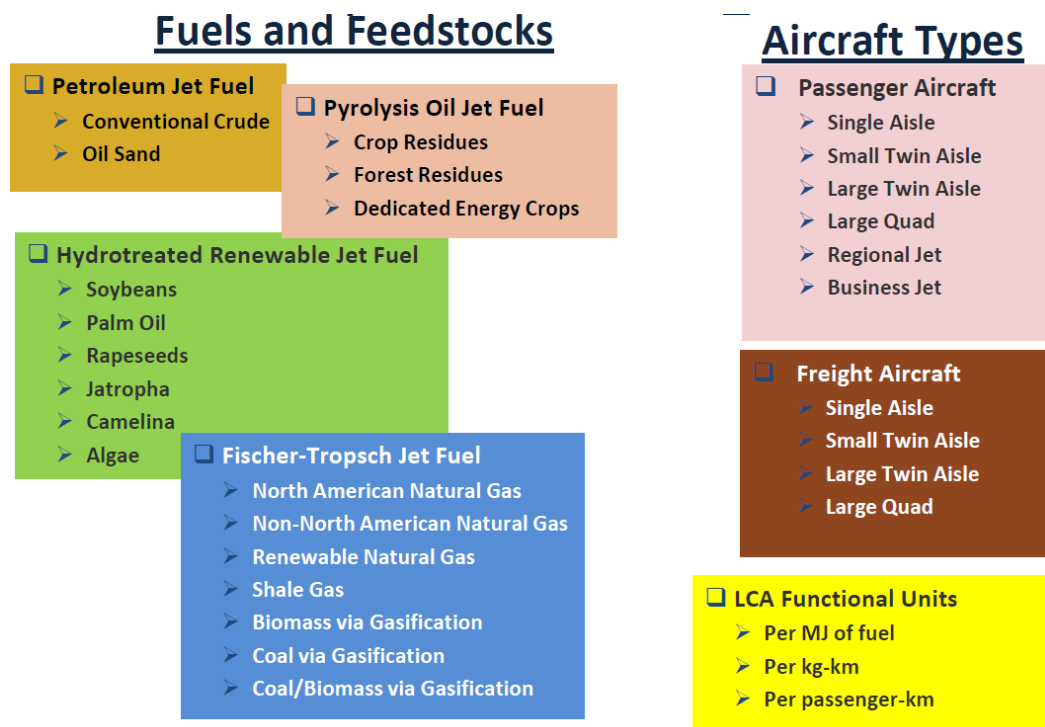
Figure 4-2. GREET1 2011 Fuel Cycle Scope



Source: Wang, 2011, Overview of Life-Cycle Analysis with the GREET Model, GREET Training Workshop, December 2011.

With its 2011 and 2012 updates, GREET expanded to more than 100 pathways, including aviation fuels and several drop-in biofuels, such as algae and cellulosic pyrolysis. The DLA-FAA joint work program supported the development of this expansion with the GREET for jet effort. Figure 4-3 highlights these added jet fuel-oriented capabilities.

Figure 4-3. GREET1 2011 Jet Fuel Capabilities



Source: Wang, 2011, Overview of Life-Cycle Analysis with the GREET Model, GREET Training Workshop, December 2011, greet.es.anl.gov/event-workshop_dec_2011.

GREET draws and compiles data from a broad variety of resources. In addition to DOE sources, it incorporates authoritative emission factors and fuel product specifications. Its development and research has resulted in model reports,

presentations, technical reports, and journal articles. Using this compiled data, GREET's analysis produces fuel life-cycle inventory results for energy/fuel use, criteria air pollutants, and GHG emissions.

NREL, PNNL, and other national laboratories host numerous complementary biofuel research, development, demonstration, and commercialization efforts. The national laboratories provide analysis and direct technical support of industry demonstration and commercialization initiatives, providing SME input on international biofuel sustainability efforts (GBEP, etc.).

NETL has led research, data, and analysis on conventional and alternative fuels that have been highly regarded and significant. While not focused on biofuels per se, NETL data and analysis on conventional fuels are the baseline against which all alternative fuels are judged for Section 526 compliance and RFS2 eligibility.

EPA

EPA's mission "is to protect human health and the environment."²³ Under these auspices, this agency is responsible for developing and enforcing environmental regulations, performs environmental research and analysis, advocates for environmental health and natural resource conservation, issues grants and sponsors partnerships, and supports public environmental awareness. In its core regulatory role, EPA's numerous programs and regions administer its environmental regulatory and enforcement responsibilities under various statutory authorities (see Chapter 3) across multiple media and program areas.

BIOFUEL ROLES

The CAA of 1990, EPCA 2005, and EISA 2007 all give EPA regulatory authority over biofuels and, ultimately, the RFS2. EPA OTAQ is responsible for the RFS2 program and for assessing its regulatory impact in the context of this legislative mandate. Every year, EPA is required to set annual standards under the RFS2 program. This includes a cellulosic biofuel volumetric standard based on projections from the Energy Information Administration (EIA) and evaluations of production capability from industry to set a minimum volume of renewable fuel in transportation fuels.²⁴

In compliance with EISA 2007, EPA's National Center for Environmental Research (NCER), in partnership with USDA and DOE, researches and develops a triennial report for Congress on the impacts of biofuel use and anticipated challenges associated with the future rise of its use. NCER researches and analyzes feedstock production, feedstock logistics, biofuels production, distribution, and end use. Studying and engagement through all parts of the supply chain life-cycle enables NCER to examine the impacts of biofuel production and its ultimate use.

²³ EPA, "Our Mission," *About EPA*, www.epa.gov/aboutepa/whatwedo.html.

²⁴ EPA, *EPA Finalizes 2012 Renewable Fuel Standards*, EPA-420-F-11-044 (Washington, DC: December 2011).

Biofuels have the potential to effect health and the environment. EPA has research programs in place to better understand the implications of exposures, environmental quality, and sustainability. EPA's Office of Research and Development (ORD) is a federal thought leader in sustainability whose R&D focus on biofuels has built on their core life-cycle inventory and analysis capability and practice.

SUSTAINABILITY RELEVANCE

NCER's triennial report to Congress is cited as an example of defining environmental sustainability indicators.²⁵ Our study considered the criteria and indicator presented in both the draft and final reports. In addition to the analysis presented on traditional feedstocks and first generation biofuels, the process and approach used in the draft report inspired the sustainability architecture's "snapshot" component, which is introduced in this Chapter 6 of this report.

OTAQ—which developed a new life-cycle GHG method to support the RFS2 rulemaking process—is an important partner in any biofuel sustainability assessment. The contemporary models did not address the entirety of the EISA life-cycle GHG mandate, so it collaboratively developed an enhanced LCA model approach that integrated both attributional and consequential components.²⁶

To evaluate transportation biofuel's GHG impacts for the RFS2 proposed and final rules, OTAQ developed hybrid LCA models that leveraged the GREET 1.8c model and two agricultural sector models, the Forestry and Agriculture Sector Optimization Model (FASOM) and the Farm and Agricultural Policy Research Institute (FAPRI). GREET provided an attributional model structure, data, and emission factor resources for the attributional LCA. EPA researched, compiled, and incorporated additional industry data to incorporate the covered feedstocks and pathways for ground transportation fuels.²⁷

Given EISA's requirement for the consideration of indirect impacts, EPA leveraged FOSOM and FAPRI to address the consequential aspects of this LCA family of models (Figure 4-4). Developed by Texas A&M University, FASOM was used to estimate land use changes in the US agricultural sector, which was then utilized to calculate the indirect land use change related GHG emissions. FAPRI-Center for Agricultural and Rural Development (CARD), developed by Iowa State University, models the "biological, technical, and economic relationships ... within a particular commodity and across commodities."²⁸ EPA leveraged this model and its outputs to account for international consequences from increased US biofuel production.

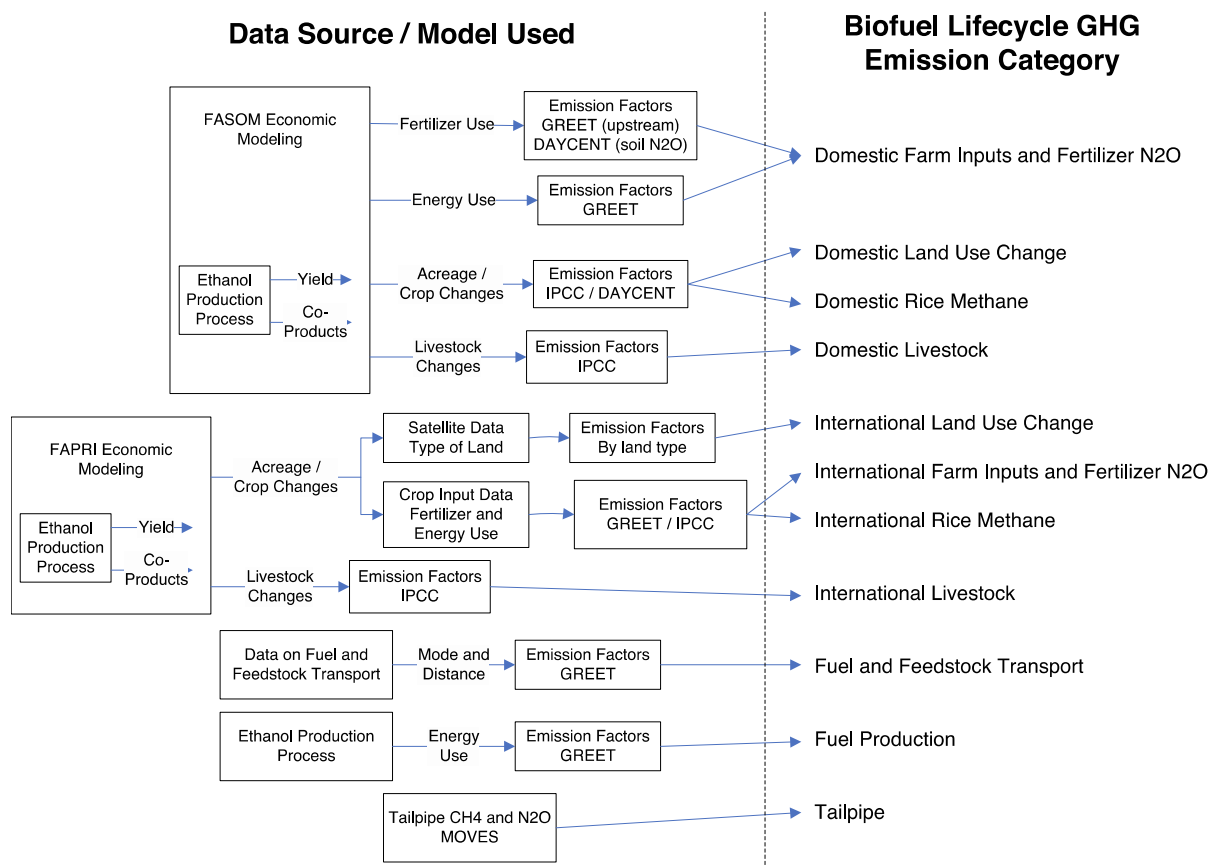
²⁵ BRD Board, *Increasing Feedstock Production for Biofuels*, (2008), www1.eere.energy.gov/biomass/pdfs/brdi_feedstock_wg2008.pdf.

²⁶ EPA, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, EPA-420-R-10-006 (Washington, DC: February 2010), www.epa.gov/oms/renewablefuels/420r10006.pdf.

²⁷ Ibid.

²⁸ Ibid.

Figure 4-4. EPA Boundary and Model Summary



Source: EPA, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis, EPA-420-R-10-006, February 2010, 302, www.epa.gov/otaq/renewablefuels/420r10006.pdf.

OTAQ's family-of-models approach is based on linked Microsoft Excel workbooks. The source data and models are all publicly available, but EPA SMEs perform the analysis, so it remains an in-house federal capability.

ORD is a leader in sustainability and is responsible for several biofuel sustainability papers and resources in recent years. Its life-cycle inventory and LCA efforts provide important resources for future sustainability analysis. Its efforts to streamline LCA efforts and develop common platforms will help maintain and streamline biofuel sustainability assessment efforts in the future.

DOT

DOT has broad authority and regulatory responsibilities for transportation infrastructure and vehicles. Its agencies have missions that require them to facilitate the integration of alternative fuels into the existing transportation system.²⁹ FAA

²⁹ BRD, "Agency Roles & Responsibilities," *BR&D*, www.usbiomassboard.gov/related_information/agency_roles_responsibilities.html.

is one of DOT's largest bureaus and has a vision "to reach the next level of safety, efficiency, environmental responsibility, and global leadership."

BIOFUEL ROLES

The FAA's Office of Policy, International Affairs and Environment "seeks to advance aviation in an environmentally responsible and energy efficient manner [by] invest[ing] in new technology, foster sustainable alternative fuels research, and advance other innovations that promote environmentally friendly solutions."³⁰ To these ends, it supports the conduct of engine component tests of drop-in biofuel blends with Jet-A and conducts laboratory tests of other advanced jet biofuel blends.³¹

FAA's Office of Environment and Energy's R&D Program supports FAA's Destination 2025 Strategic Plan. Its objective is to grow the Next Generation Air Transportation System (NextGen). NextGen aims to protect the environment in a sustainable manner and is seeking to do so through improved energy efficiency and alternative fuels development.³²

SUSTAINABILITY RELEVANCE

FAA has an MOU with USDA to enable cooperation with the airline industry to help develop feedstocks that can be converted into drop-in jet fuel products. To date, they have produced an economic pillar approach to assess feedstock maturity. This effort has produced a feedstock readiness level (FSRL) tool that assesses elements of (1) production, (2) market, (3) policy, program support, and regulatory compliance, and (4) linkage to conversion pathways.³³

This interagency partnership seeks to bring together research, feedstocks assessments, and their availability for conversion to biojet fuels. Its intent is to build off existing programs and prepare biorefineries for production of jet fuels alongside more traditional ground transportation biofuels, such as green diesel.

In December 2011, the FAA awarded \$7.7 million to eight companies to help it develop and advance alternative, sustainable drop-in jet fuels. These contracts address a Future of Aviation Advisory Committee recommendation that DOT become a leader in alternative aviation fuels. In addition, these contracts call for research into alternative jet fuel quality control, examination of how jet biofuels

³⁰ FAA, *Policy, International Affairs, and Environment Fiscal Year 2012 Business Plan*, HQ-121501 (2012), www.faa.gov/about/office_org/headquarters_offices/apl/research/.

³¹ FAA, "Environment and Energy Research & Development," *Policy, International Affairs, and Environment*, www.faa.gov/about/office_org/headquarters_offices/apl/research/.

³² Ibid.

³³ CAAFI R&D, *Feedstock Readiness Level Tool*, (November 16, 2011).

affect engine durability, and guidance to biojet fuel users about factors that affect sustainability.³⁴

The Office of Policy and Volpe Center have partnered with industry through CAAFI supporting the development of its environmental progression. The FAA and Volpe work on the CAAFI environmental progression and feedstock readiness tool are significant contributions to federal biofuel sustainability approaches.

PUBLIC-PRIVATE AND INDUSTRY EFFORTS

A4A

A4A “vigorously advocates for America’s airlines as models of safety, customer service and environmental responsibility; and as the indispensable network that drives our nation’s economy and global competitiveness”³⁵ This includes reducing fuel consumption, its resultant GHG emission reduction, energy costs stabilization through energy policies, and increased biofuel production. To accomplish its mission, A4A is involved with and supports several initiatives:

- ◆ Pledged to collaborate with USDA and Boeing in the “Farm to Fly” initiative, which aims to “accelerate the availability of a commercially viable and sustainable aviation biofuel industry in the United States, increase domestic energy security, establish regional supply chains, and support rural development.”³⁶
- ◆ Had seven of its members sign a letter of intent with Solena Fuels to provide them with jet fuel derived purely from biomass. Solena’s “GreenSky California” biomass-to-liquid plant will produce as much as 16 million gallons of neat jet fuel by 2015.
- ◆ Has an agreement with DLA Energy to group resources and purchase fuel in bulk to signal a market need. The intention is to utilize multiyear contracts for domestically created biofuels—though currently federal procurement is limited to purchasing commitments not exceeding 5 years.^{37,38}

³⁴ Biofuels Digest, “FAA awards 8 key grants to catalyze renewable jet fuel,” *BiofuelsDigest*, www.biofuelsdigest.com/bdigest/2011/12/02/faa-awards-8-key-grants-to-catalyze-renewable-jet-fuel/.

³⁵ A4A, “Mission & Vision,” *Airlines for America*, www.airlines.org/Pages/MissionVision.aspx.

³⁶ Boeing et al., *FARM to FLY – Working Together Resolution*, www.airlines.org/Documents/FarmToFlyResolution071410.pdf.

³⁷ Ibid.

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- ◆ Cofounded CAAFI to accelerate the production of alternative fuels.

CAAFI

In 2006, the FAA, A4A, and Aerospace Industries Association (AIA) created CAAFI to deal with the affordability and price stability, supply security, and environmental impacts of aviation fuel. Since then, the Airports Council International-North America (ACI-NA) has also become a program sponsor. CAAFI has about 300 non-sponsor stakeholders, including government agencies, non-governmental organizations, trade associations, fuel suppliers, international private aviation industry, and universities.

As a coalition of US commercial aviation interests, CAAFI operates as a clearing-house where private-sector and governmental entities can exchange information and coordinate initiatives that support the creation and availability of drop-in alternative aviation fuels.³⁹ CAAFI intends to “promote the development of alternative jet fuel options that offer equivalent levels of safety and compare favorably on cost with petroleum based jet fuel, while also offering environmental improvement and security of energy supply for aviation.”⁴⁰ CAAFI currently focuses on four alternative fuel topic areas:

1. *R&D*. Gather and keep up to date on new fuel technologies and potential feedstocks.
2. *Business and economics*. Conduct business case analyses of alternative fuels to facilitate deployment of alternative jet fuels in the marketplace. Build relationships between fuel producers and consumers and identify opportunities for deployment.
3. *Fuel certification and qualification*. Work through an established process to push promising biofuels through to final approval and certification for use. The reason for certification is to guarantee manufacturer and user assurance of fuels.
4. *Environment*. Assess environmental impacts of alternative fuels and measure GHG emissions of the fuel production life-cycle.

³⁸ As required by Section 863 of the FY 2012 NDAA, Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics report to the US Senate Armed Services Committee on general authorities available for long-term task and delivery order contracts for the purchase of alternative fuels. Mr. Kendal reported that 10 U.S.C. 2304a provides the DoD with the authority to enter into contracts of up to 5 years. This letter, however, reports the most contracts have been of 1-year duration and that industry has suggested that at least 10-years is needed to stimulate the investment needed to produce such fuels at commercial scale. The letter is available at: energy.defense.gov/Section_863_Long_Term_Contracting_for_Alternative_Fuels_Report.pdf

³⁹ CAAFI, “Frequently Asked Questions,” *About*, www.caafi.org/about/faq.html.

⁴⁰ CAAFI, “About CAAFI,” *About*, www.caafi.org/about/caafi.html.

CAAFI disseminates updates on these topic areas to continually move forward and accelerate the development and deployment of jet fuel alternatives. The CAAFI environmental progression parallels and complements the proposed environmental pillar criteria. Coordination with the environmental progression working group members has caused that product and the DLA Energy sustainability framework to coevolve. Furthermore, federal practitioners and not-for-profit SMEs have formed a broad community of practice in which to evolve the proposed DLA Energy sustainability architecture.

Council on Sustainable Biomass Production

Launched in 2007, the CSBP is a multi-stakeholder, member-based not-for-profit working to develop a consensus-based biomass and biofuel sustainability standard for use in the United States.⁴¹ Its purpose was “to develop voluntary sustainability standards for the production of second generation, cellulosic biomass and its conversion to bioenergy.”⁴² CSBP includes members of US industry, not-for-profit organizations, universities, and national laboratories and technical advisors from multiple DOE and USDA programs.⁴³ Focused on supporting the development of a sustainable bioenergy industry, the council considers and addresses the multiple sustainability barriers facing biomass cultivator and biofuel producers.

Version 1.0 of CSBP’s “Standard For Sustainable Production of Agricultural Biomass” was released on June 6, 2012.⁴⁴ This biomass producer’s standard relies on nine core principles: (1) integrated resource management planning, (2) soil, (3) biological diversity, (4) water, (5) air quality and emissions, (6) socioeconomic well-being, (7) legality, (8) transparency, and (9) continuous improvement.⁴⁵

The standard—and its yet-to-be-released companion “biomass consumer standard”—strives to furnish a basis for a US biomass and biofuel production sustainability certification system that could be cost-effectively applied and widely used by the industry.⁴⁶ While still under development, the CSBP standards may offer a future certification approach that addresses sustainability concerns as the industry matures and clearly differentiates biofuel products on the basis of their sustainability.

⁴¹ CSBP, Welcome to the Council on Sustainable BIOMASS Production, www.csbp.org/Home.aspx.

⁴² Ibid.

⁴³ CSBP, About Us, www.csbp.org/AboutUs.aspx.

⁴⁴ CSBP, Standard For Sustainable Production of Agricultural Biomass, Version 1.0, June 6, 2012, www.csbp.org/LinkClick.aspx?fileticket=IKMypjylZ_M%3d&tabid=87&mid=422.

⁴⁵ Ibid.

⁴⁶ See footnote 41, this chapter.

Roundtable on Sustainable Biofuels

The RSB is a multi-stakeholder initiative of government, private industry, and not-for-profit members that developed a widely regarded biofuel production and processing sustainability standard. The RSB was launched in 2007 by its Founding Steering Board and coordinated by the Energy Center of École Polytechnique Fédérale de Lausanne in Switzerland.^{47,48} RSB's international biofuel sustainability standard serves as a basis for third-party certification efforts in several countries and is approved for use by bodies such as the European Commission (EC).

Version 2.0 of the current RSB biofuel sustainability standard, “Principles & Criteria for Sustainable Biofuel Production” (RSB-STD-01-001), was developed in compliance with the ISEAL Code of Good Practice for Setting Social and Environmental Standards.⁴⁹ This standard covers the economic, environmental, and social pillars of sustainability and is based on 12 core principles: (1) legality; (2) planning, monitoring, and continuous improvement; (3) greenhouse gas emissions; (4) human and labor rights; (5) rural and social development; (6) local food security; (7) conservation; (8) soil; (9) water; (10) air; (11) use of technology, inputs, and management of waste; and (12) land rights.⁵⁰

The RSB standard was developed to support a third-party certification system. The RSB Services Foundation, a nonprofit organization, was established in the United States to manage and oversee the administration of this certification.⁵¹ RSB has developed numerous guideline documents and a “GHG Calculation and Tool” to support its certification process, which can be used to comply with the EC Renewable Energy Directive.⁵² RSB's first certification was granted in February 2012 in Australia.⁵³

Feedstock Sustainability Standards

During the course of this study, LMI identified other sustainability standards and certification systems that apply to and are tailored for specific feedstock cultivation and product industries. These standards, which all apply to biomass

⁴⁷ RSB, RSB 1st Phase (2006 - 2009), rsb.epfl.ch/page-51764-en.html.

⁴⁸ RSB, RSB Web Page, rsb.epfl.ch/.

⁴⁹ RSB, Principles & Criteria for Sustainable Biofuel Production, Global Standard, RSB-STD-01-001, Version 2.0, rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Version%202/PCs%20V2/11-03-08%20RSB%20PCs%20Version%202.pdf.

⁵⁰ Ibid.

⁵¹ RSB, Press Release, First Certification Against RSB Global Sustainability Standard Achieved By the Manildra Group, Lausanne, 2012, rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Media%20&%20Press/12-02-10%20RSB%20Manildra%20Group%20Certification%20RSB%20PR.pdf.

⁵² RSB, RSB Tools & Guidelines, rsb.epfl.ch/page-24929-en.html.

⁵³ See footnote 51, this chapter.

and cellulosic feedstocks that could be used to produce intermediates or biofuels, include the following:

- ◆ Forest Stewardship Council (FSC), FSC Principles and Criteria for Forest Stewardship, International Standard, Version 5-0, FSC-STD-01-001, www.fsc.org/
- ◆ Roundtable on Responsible Soy, Standard for Responsible Soy Production, Version 1.0, June 2010, www.responsiblesoy.org/
- ◆ Roundtable on Sustainable Palm Oil, Principles and Criteria for Sustainable Palm Oil Production, October 2007, www.rspo.org
- ◆ Bonsucro Production Standard, including Bonsucro EU Production Standard, Version 3.0, March 2011, www.bonsucro.com.

Some, such as the FSC, are long-established, well-known product certifications, while others are more recent industry efforts not yet adapted or applied in the United States. Many have been developed by members of the ISEAL Alliance or in accordance with its “Code of Good Practice for Setting Social and Environmental Standards.”⁵⁴ This code does not prescribe what sustainability should include but lays out the principles, elements, and processes necessary to produce a consensus-based and credible sustainability standard.

⁵⁴ ISEAL Alliance, Our Codes of Good Practice, www.isealliance.org/our-work/codes-of-good-practice.

Chapter 5

DoD Sustainability and Energy Security

Operational biofuels may well be the evolutionary nexus of DoD's sustainability and energy security movements, both of which have gained momentum over the last decade. Statutes and policy mandates have garnered OSD attention and resources for energy security and sustainability, but the military services, their commanders, and soldiers "got it" much earlier. Growing constraints on training lands, limited resources, energy price shocks, and a decade of combat experience revealed the perils of ignoring either. Biofuels might get a "green rap," but one fact is clear: the services aren't required by statute or policy to do much regarding the sustainability of the operational fuels used in their tactical systems and weapons platforms,¹ yet they are aggressively leading the Nation in accelerating the availability and use of next-generation, advanced biofuels. Doing so is simply a national security imperative, meant to start addressing the risks of finite and increasingly costly conventional fuels, and alternative fuels may provide some sustainable supply chain advantages.

What is DoD sustainability? What is energy security and for whom? Given the military services' energy security goals and alternative fuel targets, how many gallons of advanced, operational biofuel products are needed? What is a sustainable operational biofuel?

In this study, we focus on operational biofuels, their sustainability, and how they inform DLA Energy's ability to meet military service needs. In this context, this chapter briefly describes DoD sustainability; DoD operational energy; interagency sustainability and energy security cooperative mechanisms; defense agency biofuel efforts; military service energy security goals, initiatives, and sustainability; and, ultimately, operational biofuel demand into the future. While this chapter won't answer all these questions, it will provide the context for doing so and, more importantly, determine the scale of operational biofuels needed to meet the services' energy security requirements, which is necessary to inform the needed framework for future biofuel sustainability assessments.

DoD AND SERVICE SUSTAINABILITY

For more than a decade, the US military has been exploring, incorporating, and internalizing sustainability concepts, particularly as they apply to mission

¹ EPAAct 2005, EISA 2007, EO 13424, and EO 13514 all generally omit or outright exclude operational fuels used in tactical systems and weapons platform from any and all energy security and sustainability requirements (with exception of EISA 2007 Section 526). The primary reason for this is that operational energy is a core matter of national security operations and that are rightly relegated to our military services and DoD.

readiness. While this section is not intended as a recitation of DoD's many sustainability efforts, it briefly introduces DoD sustainability, operational energy, and how they fit together with DoD and military service energy security and sustainability efforts.

Regulatory Compliance to Service Sustainability

In the 1980s and 1990s, military installations and bases faced significant environmental compliance challenges from cold war era toxic contamination to endangered species, permit emission limits, growing reporting costs, and external encroachment pressures. As military commands improved their compliance and management capability, the installation management and acquisition communities started to embrace P2 concepts and best practices to reduce environmental compliance costs and liabilities as well as proactively reduce mission risks to training, maintenance, and capabilities. In the early- to mid-2000s, military installation and base commanders increasingly recognized that limited resources and encroachment risks could not only constrain their current and future operations, but threaten the viability of their military training and force projection capabilities.

While the DoD instituted some important programs—such as Formerly Used Defense Sites (FUDS) and Joint Land Use Study (JLUS)—to help the services address regulatory liabilities and encroachment risks, base and garrison commanders looked to sustainability as an enabling concept to take these challenges head-on and support their national defense missions into perpetuity. Military sustainability largely started as installation- and base-centric efforts. P2 efforts in the service and OSD acquisition communities expanded their environment, safety, and occupational health (ESOH) risk management paradigms and started integrating sustainability concepts. By the mid-2000s, military service secretariats and staff had already adopted sustainability strategies, such as the “US Army Strategy for the Environment,” which aligned their Title 10 military mission with vision and goals for sustainability.²

OSD and Military Service Sustainability

In 2009, EO 13514 mandated a department-level focus on sustainability across the federal government, required SSPPs, and established numerous performance metrics. Per Section 7 of this EO, all federal executive branch departments were required to designate an SSO responsible for preparing and submitting initial and subsequent SSPPs, monitoring progress, and annually reporting this progress to the agency head, the Council on Environmental Quality (CEQ), and OMB.³

² US Army, “US Army Sustainability,” *U.S. Army*, www.sustainability.army.mil/.

³ US Federal Register, *Federal Leadership in Environmental, Energy, and Economic Performance*, EO13514 (Washington, DC: October 5, 2009). and Federal Facilities Environmental Stewardship & Compliance Assistance Center, “EO 13514,” *FedCenter.gov*, www.fedcenter.gov/programs/eo13514/.

DOD SUSTAINABILITY GOVERNANCE

Dr. Ashton Carter, former Undersecretary of Defense for Acquisition, Technology and Logistics, USD (AT&L), was selected as DoD's first SSO and was responsible for the release of the FY10 and FY11 SSPPs. Per Dr. Carter's 12 April 2010 memorandum, DLA and each military service was to designate sustainability officials and staff the DoD's Senior Sustainability Council (SSC).⁴ This council's charter mandated that it

1. integrate sustainability into policies, plans, budgets and decisions;
2. make recommendations on processes and procedures to implement the requirements of EO 13514 and other federal sustainability requirements;
3. continuously improve the Department's approach to the [SSPP]; and
4. review the adequacy of policies, resources, and performance in meeting goals, and make recommendations on changes required.⁵

The SSC is co-chaired by the Deputy Under Secretary of Defense for Installations and Environment, DUSD (I&E), and the ASD (OEPP) with the latter representing the key role in operational energy, despite being largely excluded from the EO targets.

While the SSC provides leadership, guidance, and coordination for DoD's sustainability efforts, the Sustainability Implementation Work Group and its members are responsible for providing input to DoD's SSPP and "facilitating" continual improvement in achieving its goals and objectives.⁶ To do so, several existing sustainability-topic-oriented committees and work groups have been built upon and have continued working to make progress in their respective areas. According to the FY11 SSPP, current topical areas include energy (including transportation and fuels), GHGs, sustainable manufacturing, green procurement, electronic stewardship, and solid waste and recycling.

A governance structure was set up to provide leadership to, coordinate, and execute the goals and targets laid out in the DoD SSPP (Figure 5-1).

⁴ US Undersecretary of Defense, memorandum to Secretaries of the Military Departments et al., "Implementing Executive Order (EO) 13514," April 12, 2010. www.denix.osd.mil/sustainability/upload/Implementing-EO-13514-Memorandum_-12Apr10.pdf.

⁵ DoD, *Strategic Sustainability Performance Plan, FY2011*, (Washington, DC: June 29, 2011).

⁶ DoD, *Strategic Sustainability Performance Plan, FY2010*, (Washington, DC: August 26, 2010).

Figure 5-1. Sustainability Governance in the DoD



Source: DoD, *Strategic Sustainability Performance Plan*, FY11, June 29, 2011, I-10. www.denix.osd.mil/sustainability/upload/DoD-SSPP-FY11-FINAL_Oct11.pdf.

DoD SSPP

In accordance with Section 2(b) and 8 of EO 13514, DoD developed its first SSPP and released it to the public in August 2010. It identifies performance-oriented goals and objectives, lays out the means to meet them, and presents the approach for monitoring and reporting the department's performance and progress.⁷ Released in June 2011, DoD's FY11 SSPP affirms the vision that "sustainability is to maintain the ability to operate into the future without decline—either in the mission or in the natural and manufactured systems that support it."

At its core, this definition affirmed the direct purpose of and linkage between sustainability and DoD's national defense missions. The FY11 SSPP asserts DoD's commitment to not only "complying with environmental and energy statutes, regulations, and Executive Orders, but to *going beyond compliance where it serves our national security needs.*"⁸

In this context, the FY11 SSPP emphasizes four priority thrust areas:

- ◆ Energy and reliance on fossil fuels
- ◆ Chemicals of environmental concern

⁷ See footnote 5, this chapter.

⁸ US Deputy Secretary of Defense, letters to Peter Orszag and Nancy Sutley, November 18, 2009.

- ◆ Water resources management
- ◆ Maintaining readiness in the face of climate change.

The FY11 SSPP affirmed these overarching objectives, goals, and numerous sub-goals. The four strategic objectives are as follows:

1. The continued availability of resources critical to the DoD mission is ensured
2. DoD readiness maintained in the face of climate change
3. The ongoing performance of DoD assets ensured by minimizing waste and pollution
4. Continuous improvement in the DoD mission achieved through management and practices built on sustainability and community.

The FY 11 SSPP suggests these priorities can be realized by

address[ing] sustainability concepts in our acquisition and procurement processes, and in planning and managing our installations. We are committed to integrated risk management practices that protect the environment and promote sustainability while advancing our mission.

Each of the military services and defense agencies, such as DLA, have developed their own plans to implement. Some have built on their earlier sustainability strategies, goals, and efforts to accelerate the incorporation of sustainability into their operations and procurements. Energy security is often cited as a key priority and component, but the vast majority of the subgoals and metrics do not directly apply to operational energy.

Operational biofuels represent an opportunity and means for improving military service and DoD mission sustainability. However, in general, operational energy sustainability is not mandated to achieve sustainability objectives and goals. That said, the military services are focused on addressing pressing operational energy security imperatives, but these efforts can help achieve the mission by managing sustainable supply chain risks.

OPERATIONAL ENERGY PLANS AND PROGRAMS

Section 902 of NDAA FY09 added a new section 139b to Title 10, *United States Code*, to establish the position of the Director of Operational Energy Plans and Programs (DOEPP) to “provide leadership and facilitate communication regarding, and conduct oversight to manage and be accountable for, operational energy plans and programs within the DoD and the Army, Navy, Air Force, and Marine Corps.” On January 10, 2011, the NDAA FY11 was signed into law and Section 901 (B) redesignated the DOEPP position as ASD (OEP&P).

The ASD (OEP&P) is the principal advisor to the Secretary and Deputy Secretary of Defense on operational energy security and serves as a co-chair for the SSC. By statute, the ASD (OEP&P) is responsible to

- ◆ provide leadership and facilitate communication regarding, and conduct oversight to manage and be accountable for, operational energy plans and programs within DoD and the Army, Navy, Air Force, and Marine Corps;
- ◆ establish the operational energy strategy;
- ◆ coordinate and oversee planning and program activities of DoD and the Army, Navy, Air Force, and Marine Corps related to
 - implementation of the operational energy strategy;
 - consideration of operational energy demands in defense planning, requirements, and acquisition processes;
 - R&D investments related to operational energy demand and supply technologies;
- ◆ monitor and review all DoD operational energy initiatives.

Ms. Sharon Burke was sworn in as the first ASD (OEP&P) on June 25, 2010. Since then, the OASD (OEP&P) was established to “help the military services and combatant commands improve military capabilities, cut costs, and lower operational and strategic risk through better energy accounting, planning, management, and innovation.”

NDAA FY10 Section 334

Section 334 of the NDAA FY10 requires DoD to provide an assessment of the use of renewable fuels in non-tactical and tactical aviation, maritime, and ground transportation fleets and asks whether establishing a DoD commodity class for renewable fuels distinct from petroleum-based products would be beneficial. Upon the establishment of OASD (OEP&P), the office became responsible for responding to this requirement. In July 2011, OASD (OEP&P) released *Opportunities for DoD Use of Alternative and Renewable Fuels: FY10 NDAA Section 334 Congressional Study*. This report was prepared in response to the Section 334 requirement and assessed renewable fuel supply (anticipated feedstock availability, production capacity, and production) and demand (projected fuel quantities based on the military service requirements and plans) through 2020. The report reviewed statutory, regulatory, and other drivers; discussed relevant DoD and service policies, programs, and goals; projected the rapidly changing US domestic renewable fuels market; and examined the implications for DoD renewable fuel use thru 2020.

DoD Operational Energy Strategy

OASD (OEP&P) issued the *DoD Operational Energy Strategy* in June 2011. This strategy sets the overall direction for operational energy security for OSD, combatant commands, defense agencies, and military departments/services. The ultimate goal is to ensure the armed forces will have the energy resources they require to meet 21st century challenges—energy security for the warfighter. The strategy outlines a threefold approach to meet this goal:

- More fight, less fuel: Reduce the demand for energy in military operations.
- More options, less risk: Expand and secure the supply of energy to military operations.
- More capability, less cost: Build energy security into the future force.

The strategy outlines the actions DoD components should take to meet each of the goals. One of the three approaches, “expand and secure the supply of energy to military operations,” includes actions applicable to operational biofuels and states that DoD components will

Diversify and develop new energy sources suitable for expeditionary use, to include efforts aimed at developing the capacity of partner nations in support of US strategic goals:

- Promote research, development, testing, evaluation (RDT&E), and fielding of alternative energy sources that can be generated locally or regionally near deployments;
- Integrate improved and secure energy supplies into planning for and management of contingency bases; and
- Establish a joint, integrated policy and investment strategy for alternative fuels RDT&E, with guidance and oversight from the ASD (OEPP).⁹

The strategy also calls for investments in alternative fuels for research, development, test, and evaluation that are

supported by analysis on economic and technical feasibility and meet the following conditions:

- The fuels must be “drop in” (i.e., compatible with current equipment, platforms, and infrastructure);
- The fuels must be able to support an expeditionary, globally deployed force;
- There must be consideration of potential upstream and downstream consequences, such as higher food prices; and

⁹ DoD, *Energy for the Warfighter: Operational Energy Strategy*, (Washington, DC: March 1, 2011).

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- Life-cycle greenhouse gas emissions must be less than or equal to such emissions from conventional fuel.¹⁰

DoD Operational Energy Implementation Plan

In March 2012, OASD (OEP&P) issued the *DoD Operational Energy Strategy Implementation Plan*, which establishes targets and timelines to ensure DoD meets the strategy's goal of "energy security for the Warfighter." Of the supporting targets for doing so, the following are relevant to biofuels:

Target 5: Promote the Development of Alternative Fuels.

- Establish a Departmental Alternative Fuels Policy. At the Defense Operational Energy Board (2nd Quarter FY 2012), ASD (OEP&P) will present a draft Departmental policy on alternative fuels. The Defense Operational Energy Board may recommend a final policy to ASD (OEP&P), revising and updating its recommendation as needed.
- Establish a Departmental Alternative Fuels Investment Portfolio. The Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (DASD (MIBP)) will present to the Defense Operational Energy Board (4th Quarter FY 2012) a briefing on joint investments in alternative fuels using DPA authorities.¹¹

On March 22, 2012, Lieutenant General Brooks L. Bash, J-4, and Ms. Sharon E. Burke, ASD (OEP&P), signed the charter for the DoD Defense Operational Energy Board (DOEB). This charter details the DOEB's authority, scope, functions, and organization. Specific functions of the DOEB include implementing, monitoring and revising the Operational Energy Strategy.

ASD (OEP&P) Testimony

On March 29, 2012, Ms. Sharon Burke, ASD (OEP&P), testified to the Subcommittee on Readiness House Armed Services Committee, United States House of Representatives, that DoD is currently engaging in a variety of RDT&E efforts in this area of alternative fuels. The FY 2012 NDAA gave ASD (OEP&P), in consultation with the heads of the military departments and the Assistant Secretary of Defense for Research and Engineering, the authority to guide and oversee the alternative fuel activities of DoD. She also stated that her office was in the process of drafting a DoD-wide alternative fuels policy, in collaboration with the relevant DoD components, and was to present the draft to DOEB for its revisions and recommendations. This policy was intended promote the development of alternative fuels as one element of a broad energy strategy to diversifying supply.

¹⁰ Ibid.

¹¹ Ibid.

DoD Alternative Fuels Policy for Operational Platforms

On July 5th, 2012, ASD (OEP&P) transmitted the final *DoD Alternative Fuels Policy for Operational Platforms* to the DOE members. This policy is highly significant as it lays out the military purpose¹² for pursuing alternative fuels, phases categorizing such efforts, and the mechanisms to plan, evaluate, approve, and fund these activities.

Regarding the military utility and purpose, this policy states that the DoD's alternative fuels goal are to:

- ◆ ensure operational military readiness;
- ◆ improve battlespace effectiveness; and
- ◆ further flexibility of military operations through the ability to use multiple, reliable fuel sources.¹³

In doing so, it firmly asserts that alternative fuel activities are being pursued solely as “a means to ensure combat effectiveness, logistical flexibility and to mitigate Anti-Access/Area Denial (A2AD) effects” and that “DoD investments in this area will be subject to a rigorous, merit-based evaluation.”¹⁴ These DoD and military service investments are further categorized into three phases:

1. Certification/Qualification
2. Field Demonstration
3. Ongoing Purchases.

Phase 1 focuses on coordinating the military services' fuel qualification and weapons platform certification activities through the Tri-Service Petroleum, Oils, and Lubricants (POL) Users Group. This group is now responsible for developing an annual “harmonized certification/qualification plan” that is to be delivered to the DOE and recommended to ASD (OEP&P). This plan is to consider:

- ◆ drop-in compatible with existing equipment and infrastructure;

¹² Debate over the military utility and national security purpose of alternative fuel activities is elaborated in the Andrews et al., *The Navy Biofuel Initiative Under the Defense Production Act*, Congressional Research Service, June 22, 2012, www.fas.org/srg/crs/natsec/R42568.pdf. The direct language included in the new DoD Alternative Fuels Policy for Operational Platforms provides a useful statement of DoD policy on the issue while addressing many of the concerns raised.

¹³ Burke, S.E., *Department of Defense Alternative Fuels Policy for Operational Platforms*, ASD (OEP&P), July 5, 2012, energy.defense.gov/2012-7-5_DoD_Alternative_Fuels_Policy_for_Operational_Platforms.pdf.

¹⁴ Ibid.

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- ◆ ability to produce at scale and in a cost competitive manner (or production in-theater);
 - ◆ compliance with EISA Section 526; and
 - ◆ leverages industry group certification and approval activities.¹⁵

Phase 2 lays out the criteria for field demonstrations that go further than weapon platform certifications and seek to use this fuel in a broader operational environment. However, the policy explicitly states that the “demonstration must be of finite duration and its expected benefits must be clearly justified. The operational risks associated with not carrying out such a demonstration must also be described.”¹⁶ The policy outlines restrictions for use of the Defense Working Capital Fund (DWCF) to only purchase demonstration fuel and that the service must coordinate the proposed demonstration plan with DLA Energy. The approvals required for both DWCF and military service-funded demonstrations are prescribed.

Phase 3 provides guidance on future Class III supply chain purchases of alternative fuels under DLA Bulk Purchase and Direct Delivery Purchase Programs. The policy is significant as it specifies a best-value tradeoff procurement strategy while still acknowledging cost as a primary consideration and driver.

APPLICABLE INTERAGENCY MOU AUTHORITIES

DoD and EPA Sustainable and Resilient Installations

On February 7, 2012, the DoD and EPA signed an MOU to enhance their collaboration regarding the development and demonstration of innovative technologies to support DoD’s vision of sustainable and resilient military installations.¹⁷ Under this MOU, EPA and DoD will conduct joint activities to advance the development and demonstration of new technologies and applications that can be used to achieve mutual sustainability goals. EPA will use DoD installations as a platform for RDT&E of innovative technologies and approaches that will support both organizations goals of achieving sustainable and resilient natural and built infrastructure.

As discussed, several of DoD’s sustainability goals focus on reducing energy consumption and reliance on fossil fuels. Therefore, this MOU establishes a mechanism between DoD and EPA for the purpose of collaborating on installation sustainability issues. These activities could provide a venue for DoD and EPA to

¹⁵ Ibid.

¹⁶ Ibid.

¹⁷ EPA, Office of Research and Development, memorandum to the Office of the Deputy Under Secretary of Defense for Installations and Environment, “Memorandum of Understanding,” February 7, 2012.

more easily coordinate and transition applicable work to operational energy and biofuels.

DoD and DOE Energy Security Cooperation

This July 22, 2010, MOU between DOE and DoD covers efforts in the areas of energy efficiency, renewable energy, water efficiency, fossil fuels, alternative fuels, efficient transportation technologies and fueling infrastructure, grid security, smart grid, energy storage, waste to energy, basic research, mobile/deployable power, small modular reactor nuclear energy, and related areas. The purpose is to strengthen coordination between DOE and DoD in their efforts related to US strategic energy security. It facilitates the use of military installations as test beds for energy efficiency and renewable energy technologies from DOE laboratories to more quickly transition these technologies to the military end users.

USDA and Navy Biofuel and Renewable Energy MOU

On January 21, 2010, USDA and the Navy signed an MOU to promote the development of advanced biofuels and other renewable energy systems. The parties agreed to work together to support President Obama's "Blueprint for a Secure Energy Future," an initiative to build a clean energy economy, create new jobs, and reduce the US dependence on foreign oil.¹⁸ This MOU establishes a working relationship between USDA and the Navy, laying the groundwork for collaboration under the DPA Title III MOU.

USDA, DOE, and Navy DPA Title III

On March 30, 2011, the Navy, DOE, and USDA were directed by the President to work with private industry to establish advanced drop-in biofuels for use by both DoD and private-sector transportation. Subsequently, on June 28, 2011, the Navy, DOE, and USDA signed an MOU that outlines a cooperative effort to aid the development and deployment of a sustainable commercial biofuels industry, with the objective of constructing or retrofitting multiple domestic commercial or pre-commercial scale advanced drop-in biofuel plants and refineries with the following characteristics:

- Capability to produce ready drop-in replacement advanced biofuels meeting military specifications at a price competitive with petroleum;
- Geographically diverse locations for ready market access; and

¹⁸ Department of the Navy, "USDA, Navy Sign Agreement to Encourage the Development, Use of Renewable Energy," *America's Navy*, www.navy.mil/search/display.asp?story_id=50710.

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- No significant impact on the supply of agricultural commodities for the production of food.¹⁹

Under this MOU, the Navy, DOE, and USDA have agreed to fund this initiative with \$170 million each over 3 years, for an aggregate of up to \$510 million. The MOU's stated objective is to transfer funds in accordance with

- The DPA, (50 U.S.C. App. 2061 et seq);
- The Commodity Credit Corporation (CCC) Charter Act (15 U.S.C. 714 et seq);
- The Economy Act (31 USC 1535); and/or
- Other appropriate authority.

As part of this MOU, the parties agreed to establish an Executive Steering Group (ESG) to oversee and guide this initiative; coordinate decisions with DOE, Navy, and USDA leadership; and develop a plan of action and milestones covering the time frame through contract award. It also calls for the establishment of integrated product teams (IPTs) to advance the DPA process and fulfill other technical needs, as necessary.

REQUEST FOR INFORMATION

On August 29, 2011, a request for information (RFI), "Defense Production Act Title III Technology for Advanced Drop-in Biofuels Production Market Research," requested industry response concerning capabilities and market information related to advanced, drop-in biofuels production. Of particular interest, it sought information on technical, manufacturing, and market barriers to establishing a viable business for advanced, drop-in biofuels. The more than 100 responses in September 2011 show that the biofuels industry is keenly interested in responding to the military services' needs.

SPECIAL NOTICE

On March 29, 2012, a special notice informed industry that the DPA Title III Program anticipates a potential issuance of a broad agency announcement (BAA) that would request proposals from domestic sources to execute an advanced drop-in biofuel production project. This project would utilize DPA authorities to achieve military service alternative fuel goals. The then forthcoming BAA is anticipated to invite domestic sources to propose critical steps in the creation of an economically viable production capacity and supply chain for advanced drop-in biofuels.

¹⁹ US Air Force, "Defense Production Act Title III Advanced Drop-In Bio Fuels Production Project," *FedBizOpps.gov*, www.fbo.gov/index?s=opportunity&mode=form&id=e95eb37a21ff0be1eeb7679515490e3d&tab=core&_cview=0.

The special notice outlined the following requirements for the project:

1. Biofuels must be produced domestically, comply with EISA Section 526, come from an acceptable feedstock and be suitable for military operational use.
2. The proposed Integrated Biorefinery must have a rated capacity of at least 10 million gallons of neat biofuel per year.
3. The proposal must indicate that the offeror will commit to at least 50% cost share for both Phase 1 and Phase 2.²⁰

USDA, DOE, and the Navy jointly hosted the Advanced Biofuels Industry Roundtable in Washington, DC, on May 18, 2012. This roundtable offered further opportunity for engagement and partnership with the private sector toward the aim of realizing commercial production of advanced biofuels capable of powering the military and commercial aviation industries.

ADVANCED DROP-IN BIOFUEL PRODUCTION PROJECT

On June 27, 2012, the DPA Title III Program, through the DoD Executive Agent Program Office, Air Force Research Laboratory (AFRL), released a Funding Opportunity Announcement (FOA) titled “Advanced Drop-In Biofuel Production Project, which superseded the earlier Special Notice.”²¹ This FOA’s stated goal is to “establish one or more complete domestic value chains capable of producing drop-in replacement biofuels” and “form an Integrated Biofuels Production Enterprise (IBPE) comprised of partnerships that establish the complete value chain.”²²

This FOA solicited proposals from industry and laid out a two-phase progression:

- Phase 1: Planning and Preliminary Design (one-year)
- Phase 2: Construction, Commissioning and Performance Testing (up to three-years).

This competitive solicitation required a 50/50 industry cost match but was funded with \$30 million dollars of government funds, anticipated to enable up to five Phase 1 awards (up to \$6 million dollars each) by March 1, 2012.²³ Successful Phase 1 performers will then be downselected and may be invited to propose for Phase 2 funding (awards of ~\$70 million dollars each, but subject to future funding availability) to build, commission, operate, and test these IBPEs.

Industry proposers for Phase 1 are required to develop the planning and preliminary design for an IBPE “capable of producing drop-in liquid transportation fuels

²⁰ Ibid.

²¹ Ibid.

²² Ibid.

²³ AFRL, Funding Opportunity Announcement, Overview Information, Defense Production Act Title III, Advanced Drop-In Bio Fuels Production Project, FOA-12-15-PKM, <https://www.fbo.gov/utills/view?id=d786f3e7ee8301999b512409757cdfbe>.

targeted for military operational use” and “meet a target of at least 10 million gallons per year neat biofuel production capacity.”²⁴ The FOA proposals must address seven core requirements that include:

1. Biofuels must be produced domestically.
2. Biofuels must comply with EISA Section 526.
3. Biofuels must come from an acceptable feedstock.
4. Biofuels must be drop-in replacement suitable for military operational use.
5. IBPE must have a rated capacity of at least 10 million gallons of neat biofuel per year.
6. Commit to at least 50% cost share for both Phase 1 and Phase 2 and will provide Contingency Reserves during Phase 2 equal to at least 25% of total Phase 2 costs.
7. Fulfill FOA supplement elements including:
 - a. demonstration process flow diagrams;
 - b. commercial process flow diagrams;
 - c. cash flow pro-forma estimates; and
 - d. environmental questionnaires.²⁵

Phase 1 and 2 funding represents the DoD portion of funding to realize IBPEs, but this investment is likewise intended to complement the separate but coordinated USDA and DOE program funding opportunities, such as Commodity Credit Corporation funds and the Innovative Pilot and Demonstration Scale Production of Advanced Biofuels FOA.²⁶ However, the DPA FOA is explicit in that it does not include or control CCC funds or DLA Energy Offtake Agreements.²⁷

DARPA BIOFUEL PROGRAM

The DARPA Biofuel Program has been pioneering research, development, and demonstration efforts to create military-grade jet fuel (such as JP-8) from renewable biomass, cellulosic, and algal feedstocks since 2006. DARPA’s efforts are advancing approaches to create fuel from a diverse source of feedstocks while expanding the technological base for producing JP-8 at an affordable and cost-competitive price. In short, the priority thrust areas are pathway energy conversion efficiency and economic viability (as in production cost per gallon of JP-8 and total capital expenditure per gallon).

DARPA’s biofuels program has consistently sought to demonstrate economically viable and scalable feedstock conversion pathways for producing JP-8 fuels, particularly from agricultural and aquacultural crops that would not compete with

²⁴ Ibid.

²⁵ Ibid.

²⁶ Jim Lane, “The Obama plan for cost-competitive, military biofuels: The 10-Minute Guide,” July 3, 2012, Biofuelsdigest.com, www.biofuelsdigest.com/bdigest/2012/07/03/the-obama-plan-for-cost-competitive-military-biofuels-the-10-minute-guide/.

²⁷ See footnote 23, this chapter.

food supplies. The program has been supporting renewable biomass, cellulosic, and algal feedstock focused efforts to

1. produce JP-8 costing less than \$3 per gallon to produce;
2. realize production cost at a pilot scale (< 50 million gallons per year); and
3. demonstrate production pathways that are broadly applicable and scalable as to have significant and positive impact on DoD.

DARPA set ambitious and laudable goals for its cellulosic biofuels efforts. It first sought to demonstrate a cellulosic-based jet fuel pathway with a 30 percent energy conversion efficiency, from feedstock material into JP-8, and to do so with a projected, commercial scale (50 million gallons per year) production cost of less than \$3 per gallon of JP-8. The program's second goal for cellulosic-based jet fuel was to demonstrate an even higher energy conversion efficiency of 50 percent and likewise do so at a commercial scale production with a cost of under \$3 per gallon of JP-8.

For algal feedstock efforts, its first goal was to realize algal systems that produce \$2-per-gallon triglyceride oil and show a projected JP-8 production cost of less than \$3 per gallon at commercial scale (50 million gallons per year). Second, the program sought to reach a further threshold of algal systems producing \$1-per-gallon triglyceride oil and achieve a projected cost of production less than \$3 per gallon of JP-8 at commercial-scale production.

As the program has evolved, it has expanded to demonstrate a combined technology alcohol-to-jet conversion pathway.

Select Initiatives

DARPA has recently funded several feedstock-to-biofuel pathways, namely algae-to-jet, cellulosic-to-jet, and alcohol-to-jet. The BAA is funding four performers:

1. *General Atomics (with SAIC)*. Aims to realize cost-effective production of algal oil feedstocks that can be converted to HEFA.
2. *Logos Technologies (Terrabon, Inc.)*. Focuses on cellulosic feedstock—corn stover, switchgrass, wood chips, and municipal solid waste (MSW)—conversion to alcohols via anaerobic fermentation, alcohol oligomerization, and hydrotreatment.

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3. *Lanzatech*. Demonstrates conversion of industrial carbon monoxide (CO) emissions via gas fermentation with engineered microbes to ethanol or other intermediates.²⁸
 4. *Swedish Biofuels (with and independent of Lanzatech)*. Focuses on conversion of cellulosic feedstocks to jet fuel via alcohol oligomerization and hydrotreatment.

DARPA funded demonstration testing in 2011–12 and planned a transition to the program’s final phase, full-scale production by 2013 at the pilot sites in Hawaii and Texas.

Alignment with Sustainability Criteria and Metrics

DARPA’s biofuel program focuses on testing and demonstrating the technical and economic viability of drop-in biofuel conversion pathways. Key models and metrics have included

- ◆ energy conversion efficiency,
- ◆ production cost per gallon of JP-8,
- ◆ total capital expenditure per gallon of JP-8,
- ◆ debt-equity ratio, and
- ◆ internal rate of return.

The program’s experience with cellulosic F-T conversion technologies suggested the importance of considering water demand and GHG factors because of their potential as barriers to deployment. It considers these factors but generally does not consider the broader scope of environmental or social criteria. Between these and the economic viability factors, the algal pathways explored have typically incorporated labor, land required, water use, and water recharge in their business models. Of these criteria, DARPA specifically noted challenges with calculating life-cycle GHG emissions because of uncertainties in accounting for co-product allocation and input production variations, such as hydrogen production from natural gas reforming and electrolyses.

²⁸ LanzaTech, “The LanzaTech Process,” *LanzaTech*, www.lanzatech.com/content/lanzatech-process. and LanzaTech, *Spearheading New Ideas in Bio-commodity Technology*, (Roselle, IL: 2010).

DLA ENERGY ALTERNATIVE AND RENEWABLE FUELS PROGRAM

DLA Energy's mission is to "provide DoD and other government agencies with comprehensive energy solutions in the most effective and efficient manner possible." Past DLA director's guidance charged the organization to seek "innovative and practical alternative fuels and renewable energy solutions that make our nation less dependent on foreign sources of energy and comply with environmental requirements."²⁹ DLA Energy has been responsible for "partner[ing] with the Services in developing alternative fuels and renewable energy solutions (AFRE) to meet the department's immediate and future needs."³⁰ In response to this charge, DLA Energy diligently worked to achieve AFRE objectives:

- Synchronize with military services and other federal customers to ensure a formalized AFRE requirements identification process.
- Advance AFRE 'state of knowledge' by executing research and development projects.
- Determine alternative fuel industrial production and distribution capabilities to serve as a baseline for alternative fuel strategic planning.
- Leverage the Air Transport Association strategic alliance to address and mitigate alternative fuel industry development obstacles/issues.
- Engage and enable to support DoD efforts to acquire operational quantities of alternative fuels.³¹

DLA Energy has reinforced its key role as a focal point, technical resource, and strategic partner in helping the services realize their respective alternative and renewable fuel goals and objectives. Examples of their key technical and procurement support activities include

- ◆ conducting numerous R&D studies to advance the state of knowledge involving the intricacies of AFRE development, the potential for operational usage (the Section 334 report), and drop-in biofuel sustainability (this study);
- ◆ procuring 730,000 gallons of neat synthetic F-T fuels;
- ◆ procuring over a million gallons of neat biomass-derived HEFA fuels in support of services' testing, certification, and demonstration efforts;
- ◆ contributing to and sponsoring interagency efforts to address R&D gaps (the statement of work [SOW] with FAA on environmental cost and benefit analysis); and

²⁹ DLA, *2011 Director's Guidance*, (Washington, DC).

³⁰ Ibid.

³¹ Ibid.

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- ◆ providing technical review and advice in support of the DPA.

In March 2010, DLA Energy representatives signed a strategic alliance with A4A to promote widespread commercialization of environmentally friendly aviation fuels with less reliance on fossil fuels.³² The agreement highlights the shared goals of DoD and the principal US airlines to advance the development and deployment of commercially viable and environmentally friendly alternative aviation fuels.

Select Initiatives

In April 2012, DLA issued *2012 Director's Guidance* which reinforces and expands DLA Energy's growing AFRE responsibilities in Warfighter Support 5 (WS-5), "Support the Department's Operational Energy strategy to enhance warfighter agility."³³ Under this initiative, the DLA Energy team has been directed to

- Support DoD efforts in alternative fuel policy development and supply chain integration.
- Support the Title III Biorefinery Development initiative co-led by the Department of the Navy, Department of Energy and Department of Agriculture.
- Provide acquisition support for the 2012 Navy Green Fleet local operations demonstration.³⁴

To these ends, the DLA Energy team has been assigned responsibilities to participate and contribute to the DOEB and the DPA Title III initiative working groups. These efforts are intended to support the realization of the *Operational Energy Strategy Implementation Plan*, the Navy's "Green Fleet" demonstration, and ultimate deployment of DPA-sponsored commercial-scale biorefineries.

Moving forward, DLA Energy is expected to continue its leading-edge support for OSD and military service alternative and renewable fuel aspirations via the procurement, due diligence technical review, and R&D roles (Chapter 1).

Alignment with Sustainability

DLA is responsible for demonstrating and reporting annual progress toward the goals and targets found in the DoD SSPP. As discussed, the vast majority of these goals and objectives directly focus on facilities performance and environmental management. These largely apply to installation support and are not prescriptive in the context of operational biofuels due to the flow down exclusion in Section 18 of EO 13514.

³² Kelly Widener, "Defense Department, Airlines Sign Alternative Fuels Pact," *Defense Energy Support Center*, www.defense.gov/news/newsarticle.aspx?id=58414.

³³ DLA, *2012 Director's Guidance*, (Washington, DC).

³⁴ Ibid.

However, the FY11 progress report on the DoD SSPP and DLA's FY12 DoD SSPP implementation plan identify progress and next steps regarding Goal 7, Sustainability Practices Become Norm, specifically Subgoal 7.1, 95 percent of Procurement Conducted Sustainably. Such affirmative procurement initiatives have traditionally focused on compliance with established EPA and USDA (biopreferred) programs for office supplies and consumables, which specifically exclude energy commodities. But, sustainable procurement efforts have expanded under the auspices of EO 13514 to also consider nontraditional products, such as consulting services. POL product procurements are also starting to be an area of sustainable procurement focus, and DLA Aviation's demonstration of biobased penetrating lubricants was presented in DLA's FY11 SSPP progress report. It also specified several DLA-wise procurement initiatives and called for an expanded use of the Integrated Acquisition Review Board (IARB).

DLA Energy is a customer-centric organization and will seek to provide the military services with the drop-in biofuels they request and require. In doing so, the DLA Energy team will endeavor to consider the sustainability criteria identified and provide the procurement, technical review, and R&D support for those aspirations. In support of these roles, this report presents a proposed DLA Energy AFRE sustainability architecture, framework, and assessment process, which have been developed to consistently inform DLA Energy's execution of its roles.

ARMY ENERGY SECURITY AND SUSTAINABILITY

The Army released its *Army Energy Security Implementation Strategy* (AESIS) in 2009. The strategy aims to increase energy security by advancing energy options that ensure surety, survivability, supply, sufficiency, and sustainability.

The strategy sets forth several goals and component objectives. Relevant to this report, AESIS Energy Security Goal 3 is to "increase use of renewable and alternative energy."³⁵ Objectives supporting this goal that are fuel related include the following:

- ◆ AESIS Objective 3.1 is to "substitute renewable resources for purchases of energy and fuel from fossil fuel sources where life-cycle is cost effective." The associated metric is stated as "% of electric and total energy from renewable sources."
- ◆ AESIS Objective 3.3 is to "transition from fossil fuel based tactical mobility/power generation to alternative/renewable energy/sources." The metrics that measure this objective are driving much of the Army's current operational biofuel qualification efforts. These metrics and targets are as follows:

³⁵ The Army Senior Energy Council and the Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships, *Army Energy Security Implementation Strategy*, (Washington, DC: January 13, 2009).

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- *Metric 3.3a.* Percentage of Army tactical ground equipment systems for which alternative or renewable fuels and synthetic fuel blend evaluations are completed. Targets are 50 percent by the end of FY12 and 100 percent by the end of FY14.³⁶
 - *Metric 3.3b.* Percentage of Army engine and aviation systems for which alternative or renewable fuels and synthetic fuel blend evaluations are completed. Targets are 50 percent by the end of FY14 and 100 percent by the end of FY16.
 - *Metric 3.3d.* Percentage of Army area of responsibility power generation requirements met by renewable or alternative sources. Target is 50 percent by the end of FY10.³⁷

In September 2010, the Army released the *Tactical Fuel and Energy Implementation Plan*, which recommends timelines, operational tasks, responsibilities, and quantitative metrics to measure progress toward the AESIS objectives and metrics. For AESIS Energy Security Goal 3, the plan proposes the following quantitative metrics:

- ◆ By FY18, at least 15 percent of the training bases' fuel requirements are met by alternative fuel blends.
- ◆ By FY23, at least 30 percent of the training bases' fuel requirements are met by alternative fuel blends.
- ◆ By FY28, at least 50 percent of the training bases' fuel requirements are met by alternative fuel blends.

Ms. Katherine Hammack, Assistant Secretary of the Army for Installations, Energy and Environment, ASA(IE&E), issued the caveat that the Army “stand[s] ready to use alternative fuels when industry can produce them at a volume and price we can afford.”³⁸ This statement suggests that the Army policy is identical to that of the Air Force, and now the Navy, in that it will use operational biofuels when available and price competitive.

Select Initiatives and Milestones

In May 2010, the Army performed a flight demonstration test at Redstone Airfield and proved the viability of using a 50/50 blend of F-T SPK (coal to liquid) and

³⁶ The Metric 3.3a target for 100-percent qualification was set by the AESIS for October 2013. Recent public statements by Ms. Katherine Hammack, ASA(IE&E) have suggested that this milestone will be met by the end of 2013.

³⁷ Dennis K. Bohannon, “Green Warrior Convoy Announced – ‘It’s about saving Soldiers’ lives’,” *U.S. Army*, www.army.mil/article/77690/Green_Warrior_Convoy_Announced____It_s_about_saving_Soldiers__lives_/.

³⁸ Ibid.

JP-8 using the Black Hawk helicopter.^{39,40} Currently, the Army is working to obtain Air Force certification for H-60 aircraft (Black Hawk to the Army and Pave Hawk to the Air Force) to fly on the 50/50 FT-SPK/JP-8 blend.⁴¹

On April 11, 2012, the Army opened the Ground Vehicle Power and Energy Laboratory (GSPEL) complex at the Detroit Arsenal in Warren, MI. The laboratory is responsible for developing cutting-edge energy technologies for the next generation of combat vehicles and will support the launch of the Army Green Warrior Convoy. This convoy is to be assembled in 2013 as part of required road tests of advanced energy technologies and systems developed at GSPEL. The convoy will travel from Warren, MI to Washington, DC, and will test and demonstrate the Army's advanced vehicle power and technology, including fuel cells, hybrid systems, battery technologies, and alternative fuels.

Alignment with Sustainability

AESIS primarily focuses on energy security, but AESIS Objective 3.2 explicitly cites GHG emission reduction in the context of biofuel use in non-tactical vehicle fleets. In December 2011, the Army Environmental Policy Institute (AEPI) released the *Army Water Security Strategy*. This release complements ASA (IE&E) priority initiatives, such as Net Zero (installations), focusing on solutions balancing and optimizing measures of energy, water, and waste. More broadly, the Army's robust organizational sustainability approach and efforts are annually documented in the *Army Sustainability Report* (ASR). Both the 2011 and 2012 ASRs have been structured around the Army's four tenets of sustainability: "materiel," "readiness," "human capital," and "services and infrastructure." The ASR is prepared utilizing the Global Reporting Initiative framework. The 2012 ASR discusses the Army's progress against its sustainability metrics for 2010 and 2011 as well as their efforts to implement and institutionalize sustainability practices throughout the Army.⁴²

The *Army Sustainability Campaign Plan* (ASCP), finalized in 2010, likewise describes the Army's four tenets of sustainability and establishes sustainability as an organizing principle across the Army's missions and functions. The ASCP serves as the Army's SSPP and helps to align and integrate ongoing efforts with the new and necessary plans and programs to address DoD objectives in implementing EO 13514.⁴³

³⁹ Kari Hawkins, "Flying Skies with Coal Mix Fuel," *U.S. Army*, www.army.mil/-news/2010/07/30/43075-flying-skies-with-coal-mix-fuel/.

⁴⁰ Army Energy Program, "Alternative Fuel Vehicles," *Army Energy Program*, army-energy.hqda.pentagon.mil/programs/afv1.asp.

⁴¹ See footnote 28, this chapter.

⁴² US Army, *Army Releases Sustainability Report*, 2012, http://www.army.mil/article/89984/Army_Releases_Sustainability_Report_2012/

⁴³ US Army, *Army Sustainability Campaign Plan*, (May 12, 2010).

AIR FORCE ENERGY SECURITY AND SUSTAINABILITY

The *Air Force Energy Strategy*, released in 2009, set goals to certify its entire fleet of weapons platforms to use a 50/50 synthetic blends by 2011 (see “Select Initiatives and Milestones Achieved”). The energy strategy also set a goal to cost competitively acquire 50 percent of its contiguous United States (CONUS) aviation fuel via a synthetic fuel blend utilizing domestic feedstocks by 2016.

The Air Force 2010 *Energy Plan* sets energy end state goals for 2030, one of which is to fly aircraft on alternative fuel blends when they (1) are cost-effective, (2) are domestically produced, and (3) have a life-cycle GHG footprint equal to or smaller than that of petroleum (EISA Section 526 compliant). The plan also establishes the Air Force goal to acquire 50 percent of the domestic aviation fuel requirement via an alternative fuel greener than conventional petroleum by 2016.⁴⁴

Select Initiatives and Milestones

The Air Force has led the way in developing the test and demonstration processes used in weapons platform certification of synthetic and drop-in biofuel blend use. The AFRL is the Air Force’s R&D organization and manages its science and technology program. Over the past half decade, AFRL at Wright-Patterson Air Force Base, OH has been a focal point and authority in analytical testing and characterization of several alternative jet fuel blend stocks, such as F-T SPK, and HEFA.⁴⁵ Its testing of HEFA blend stock is credited with provided key data that help accelerate this product’s approval by ASTM International in 2011. AFRL continues its important role in characterizing new drop-in biofuels, such as ATJs and catalytic renewable jet (CRJs). For example, AFRL tested and released analytical results for a cellulosic, ATJ pathway, produced by Virent and Shell, that yield promising characteristics for a fully synthetic, drop-in jet fuel.⁴⁶

Once these new fuels’ properties are characterized, the Alternative Fuel Certification Division (AFCD) at Wright-Patterson Air Force Base plays a key role in testing and screening new drop-in biofuels and has been responsible for three separate synthetic fuel certification efforts. AFCD’s first certification program focused on JP-8/SPK, which is a 50 percent JP-8 and 50 percent F-T derived SPK.

⁴⁴ US Air Force, *Air Force Energy Plan*, (2010), www.safie.hq.af.mil.

⁴⁵ DoD, Opportunities for DoD Use of Alternative and Renewable Fuels: FY10 NDAA Section 334 Congressional Study, OASD (OEP&P), energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf

⁴⁶ Biofuelsdigest.com, Air Force says Virent alcohol-to-jet fuel passes first tests, October 10, 2011, <http://www.biofuelsdigest.com/bdigest/2011/10/10/air-force-says-virent-alcohol-to-jet-fuel-passes-first-tests/>.

All Air Force weapons platforms were certified to use SPK blended JP-8 as of April 2012.⁴⁷

AFCD executed a second, ground breaking testing and certification program for HEFA jet fuel. HEFA blend stock is synthesized from biomass feedstocks, such as animal fats and plant oils (including algal oils). Starting with the initial A-10C certification flights in March 2010,⁴⁸ this program has already successfully certified the vast majority of USAF weapons platforms for use of HEFA blended JP-8 and is anticipated to finish the remaining platforms by December 2012, with the exception of the F-22 program.⁴⁹

In late-2011, AFCD started its testing of a third alternative fuel blend, comprised of 50 percent JP-8 and 50 percent alcohol-to-jet (ATJ) blend stock.⁵⁰ The ATJ blend being tested and certified is derived from butanol, an alcohol intermediate feedstock, that is synthesized to SPK and blended with conventional JP-8.^{51,52} All Air Force weapons platforms should be certified to use ATJ fuel blends by 2014.⁵³

Alignment with Sustainability

The 2009 *Air Force Energy Strategy* focuses on core criteria across operational, economic, and environmental sustainability pillars, such as ensuring certification, domestic energy security (energy security and availability), cost competitiveness (economic viability), and “greener” characteristics than conventional fuels (environmental pillar). The strategy states the intent to require that synthetic fuel purchases are sourced from suppliers with manufacturing facilities that engage in CO₂ capture and effective reuse (EISA Section 526 compliant).

The Air Force 2010 *Energy Plan* emphasizes the desire to develop, evaluate, and certify promising operational biofuels, not only for technical suitability (operational sustainability), but also for environmental compliance and sustainability. The plan also identifies and establishes a midterm objective to “identify, inventory, understand, and potentially reduce the life-cycle GHG emission impact from aviation and ground operations.”⁵⁴ In short, this objective not only sets a life-

⁴⁷ US Air Force Petroleum Agency (AFPA), Commander, Personal Communication, September 20, 2012.

⁴⁸ Samuel King, Air Force officials take step toward cleaner fuel, energy independence, USAF, 3/25/2010, www.af.mil/news/story.asp?id=123196846.

⁴⁹ See footnote 47, this chapter.

⁵⁰ Walston, Jeff, “Barksdale Airmen test alternative fuel jet,” *Air Force Reserve Command*, www.afrc.af.mil/news/story.asp?id=123297400.

⁵¹ Ibid.

⁵² Walston, Jeff, A-10 first aircraft to use alcohol-based fuel, 307th Bomb Wing, USAF, www.af.mil/news/story.asp?id=123308337.

⁵³ Air Force Magazine, “Air Force World,” *Online Journal of the Air Force Association*, www.airforce-magazine.com/MagazineArchive/Pages/2012/May%202012/0512world.aspx.

⁵⁴ See footnote 44, this chapter.

cycle GHG metric but a commitment to developing consistent and accepted methods for its calculation.

NAVY ENERGY SECURITY AND SUSTAINABILITY

The Navy released *A Navy Energy Vision for the 21st Century* in October 2010. This strategy outlines the Navy's energy vision, which values energy as a strategic resource, acknowledges energy security as fundamental to executing the Navy's mission afloat and ashore, and creates a Navy that is resilient to any potential energy future.

The Navy translated this vision into "strategic imperatives" (assure mobility, protect critical infrastructure, lighten the load, expand tactical reach, and green our footprint) that will facilitate the achievement of the Secretary of the Navy's five energy goals:

1. *Increase alternatives afloat.* By 2020, 50 percent of total Navy energy consumption will come from alternative sources.
2. *Increase alternatives ashore.* By 2020, the Navy will produce at least 50 percent of shore-based energy requirements from alternative sources.
3. *Sail the "Great Green Fleet."* The Navy will demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016.
4. *Reduce non-tactical petroleum use.* By 2015, the Navy will reduce petroleum use in the commercial vehicle fleet by 50 percent.
5. *Energy efficient acquisition.* Evaluation of energy factors will be mandatory when awarding contracts for systems and buildings.

The *Energy Program for Security and Independence* sets the Navy's energy course to achieve its energy goals through five strategic program elements focused on "increasing the energy efficiency of tactical and shore systems, increasing the use of alternative energy, and maintaining a steadfast commitment to environmental stewardship."⁵⁵ These strategic program elements include:

- Energy efficient acquisition. Incorporate energy efficiency into decisions for new systems and buildings.
- Energy management. Create an energy management structure through improved governance, planning, programming, and budgeting.
- Behavior change. Improve energy management communication and awareness through training, education, and recognition programs to drive culture change.

⁵⁵Department of the Navy, *Department of the Navy's Energy Program for Security and Independence*.

- Science and technology. Accelerate the adoption of nascent advanced technologies and foster partnerships with other federal agencies, universities, and laboratories to research, mature, and demonstrate new technologies.
- Strategic partnerships. Cultivate partnerships with existing and new organizations and leverage partner resources and capabilities to construct and execute the Navy's energy programs.⁵⁶

Select Initiatives and Milestones

Over the past several years, the Navy has made significant efforts focused on testing and certification of drop-in biofuels. In April 2010, the Navy flew the F/A-18 Super Hornet multirole fighter jet, nicknamed the “Green Hornet” on a 50/50 blend of conventional jet fuel and HEFA blend stock produced from camelina oil. The F/A-18 Super Hornet subsequently received final approval and certification for the use of HEFA blended jet fuel.⁵⁷ Since these initial test flights, the Navy has successfully conducted biofuel testing and certification flights on a wide range of aircraft, including the MH-60 Seahawk, MQ-8 Fire Scout, AV-8B Harrier, EA-6B Prowler, and T-45 Goshawk. In February 2012, Navy Secretary Ray Mabus stated, “[w]e’ve certified all our aircraft, every aircraft the Navy and Marine Corp fly for biofuels. We’re doing the same thing with our surface fleet today.”⁵⁸ The Navy subsequently tested several surface platforms, such as the Riverine Command Boat (RCB-X) and the USS *Paul F. Foster* destroyer. The certification of the Navy’s surface and aviation weapon platforms were all important milestones leading toward and enabling the Green Strike Group demonstration held during the July 2012 Rim of the Pacific (RIMPAC) Exercise.⁵⁹

In support of the Green Strike Group demonstration, DLA Energy, on behalf of the Navy, purchased 450,000 gallons of operational biofuel in December 2011, including 100,000 gallons of neat HEFA jet and 350,000 gallons HEFA diesel, which were blended 50/50 with JP-5 and F-76, respectively. The Navy used these advanced biofuels blends to power the non-nuclear surface vessels and naval aviation assets during RIMPAC 2012.⁶⁰ This successful demonstration was a significant milestone in achieving the Navy’s third energy goal (“Sail the ‘Great Green Fleet’”). Assuming the availability of cost competitive drop-in biofuels,^{61,62,63} the

⁵⁶ Ibid.

⁵⁷ Chris Tindal, “Department of Navy Biofuel Initiatives” (presentation, South Dakota State University Industry Forum, October 5, 2011).

⁵⁸ Jim Lane, “Aviation and military biofuels: new thinking on finance, fuels,” *BiofuelsDigest*, www.biofuelsdigest.com/bdigest/2012/02/08/aviation-and-military-biofuels-new-thinking-on-finance-fuels/.

⁵⁹ Todd Woody, The Navy's Great Green Fleet Strikes Back Forbes, Green Tech, 7/19/2012, www.forbes.com/sites/toddwoody/2012/07/19/the-navys-great-green-fleet-strikes-back/.

⁶⁰ American Forces Press Service, Navy Oiler Delivers Biofuel for RIMPAC Exercise, July 18, 2012, www.defense.gov/news/newsarticle.aspx?id=117174.

⁶¹ Tom Hicks, Navy: We’ll Never, Ever Overpay for Biofuels, Wired Magazine, Danger Room, July 27, 2012, <http://www.wired.com/dangerroom/2012/07/biofuel-pushback/>.

Navy plans to sail the “Great Green Fleet” in 2016 using 50/50 biofuel blends with JP-5 and F-76. This carrier task force is anticipated to require 80,000 barrels of alternative fuel blend stock (1,680,000 gallons of neat HRJ-5 and 1,680,000 gallons of neat HRF-76).⁶⁴

Alignment with Sustainability

A Navy Energy Vision for the 21st Century primarily focuses on energy security (operational pillar) but effectively integrates criteria across the remaining sustainability pillars (economic, environmental, and social). It notes that a “sustainable non-petroleum based fuel supply is a foundation for energy security for the Navy and the Nation.”⁶⁵ The goals to increase alternatives afloat and ashore both identify criteria across these pillars. Economic sustainability is reflected in the requirement for a “robust [biofuel] industry,” which emphasizes criteria such as economic viability to achieve supply availability. Environmental criteria, specifically the need for lower GHG-emitting alternative fuels, energy’s linkages with climate change, and the need to adapt to that change are mentioned in several instances as well as the Navy’s “commit[ment] to continue a strong legacy of environmental stewardship.”⁶⁶ While less pronounced, the vision also alludes to social criteria, such as food security, when discussing current “non-food” derived alternative fuels currently being evaluated. The Navy calls for sustainable operational fuels and identifies the criteria and attributes of this fuel, but it has provided flexibility in not explicitly or restrictively defining sustainable biofuels.

MARINE CORPS ENERGY SECURITY AND SUSTAINABILITY

In August 2009, the Commandant declared energy a top priority for the US Marine Corps (USMC).⁶⁷ In October 2009, he created the USMC Expeditionary Energy Office (E²O), with the mission of analyzing, developing, and directing “the Marine Corps’ energy strategy in order to optimize expeditionary capabilities

⁶² Dan Parsons, Navy Secretary Won’t Back Off From Renewable Energy Goals (Updated), National Defense Magazine, 10/17/12, www.nationaldefensemagazine.org/blog/Lists/Posts/Post.aspx?ID=930.

⁶³ Dan Parsons, Who Is Responsible for Making Biofuels Affordable?, National Defense Magazine, 10/19/12, www.nationaldefensemagazine.org/blog/Lists/Posts/Post.aspx?ID=933.

⁶⁴ US Naval Supply Systems Command, Alternative Fuels Logistics Program Manager, Personal Communication, March 15, 2011.

⁶⁵ Department of the Navy, *A Navy Energy Vision for the 21st Century*, (October 2010), p.6.

⁶⁶ Department of the Navy, *A Navy Energy Vision for the 21st Century*, (October 2010), p. 2.

⁶⁷ USMC, “USMC Energy Summit – August 13, 2009 – Washington, DC,” *Marines*, www.marines.mil/unit/logistics/Pages/Conferences/USMCEnergySummit/USMCEnergySummit.aspx.

across all warfighting functions.”⁶⁸ By March 2011, the Commandant issued USMC *Expeditionary Energy Strategy and Implementation Guidance*. This comprehensive “Bases-to-Battlefield” document established Marine Corps operational and installations energy goals, and aligned these with guidance and mandates established by civilian and military leadership.

The Strategy’s stated mission is to “by 2025 ...deploy Marine Expeditionary Forces that can maneuver from the sea and sustain its C4I [command, control, communications, computers, and intelligence] and life support systems in place; the only liquid fuel needed will be for mobility systems, which will be more energy efficient than systems are today.” This is driving the Marine Corps broad objective to increase their battlefield operational energy efficiency by 50 percent per day per marine in a manner decreasing the logistics demand for liquid fuels. To achieve this mission, the Marine Corps is pursuing three principal goals:

- ◆ centering ethos on operational energy;
- ◆ increasing efficiency; and
- ◆ meeting operational demand with renewable energy.

Installations-related goals center on mandated requirements for reducing energy intensity, reducing water consumption, reducing non-tactical petroleum, and increasing use of alternative energy.

The Navy has the lead for biofuel development, with the USMC playing a supporting role. The Marine Corps is working closely with the Navy to ensure that any drop-in biofuel requires minimum changes to existing vehicles and equipment. Drop-in biofuel must meet existing fuel standards which, in turn, reduce qualification testing requirements. The US Army and its Tank Automotive Research, Development and Engineering Center (TARDEC) have the lead for qualifying alternative fuels for use in common tactical vehicles. However, the Marine Corps will conduct limited evaluations on USMC-specific vehicles to qualify the use of drop-in biofuels.

The Strategy’s “Implementation Planning Guidance” identifies tasks and responsibilities, as well as time frames for their execution and achievement. The primary task relevant to operational biofuels is “NLT June 2011, [Deputy Commandant Combat Development and Integration], in coordination with [Marine Corps Systems Command], assess and develop a program plan to certify Marine Corps equipment on alternative fuels. This plan will track with Department of the Navy alternative fuel initiatives and program timelines.”⁶⁹

⁶⁸ Assistant Commandant of the Marine Corp, Memorandum 11/09, “Establishment of the Marine Corps Expeditionary Energy Office,” November 19, 2009.

⁶⁹ USMC, *United States Marine Corps Expeditionary Energy Strategy and Implementation Plan*, (Washington, DC).

On August 1, 2011, the USMC released *Initial Capabilities Document for United States Marine Corps Expeditionary Energy, Water and Waste (E2W2)*⁷⁰ that describes needs, gaps, and solution approaches related to expeditionary energy, water, and waste. These needs are based on a capabilities-based assessment that provides the analytical basis for requirements that will drive development and fielding of a comprehensive E2W2 capability set.

Select Initiatives and Milestones

The Navy Fuels Team, led by the Naval Air Command (NAVAIR), is incorporating select Marine Corps aviation equipment into the alternative fuels test and qualification program. For example, in August 2011, the Navy and Marine Corps successfully conducted a biofuel certification test on a Marine Corps MV-22 Osprey, a multi-mission aircraft.⁷¹

Alignment with Sustainability

The Marine Corps Strategy keenly focuses on operational energy, but it also addresses sustainability and environmental criteria in the context of installations energy programs. It notes that the Marine Corps is aligned with and supports the Navy energy security and alternative fuel afloat efforts, which would likely reflect the related sustainability criteria priorities.

The Marine Corps installations energy program, as outlined in the Strategy, broadly emphasizes the need for sustainability and sustainable practices as well as specifically calling out considerations, such as GHG emissions, water demand, and waste disposal. Notably, water is a priority for both installations sustainability and the battlefield because of the logistics tail and risks involved with providing water at forward outposts and patrol bases.

The 2011 *United States Marine Corps Sustainability Plan* provides a broader but equally useful perspective in describing its three overarching sustainability goals for installations:

1. Improve energy and water resources management and reduce greenhouse gases;
2. Minimize waste and prevent pollution; and
3. Improve integration of sustainability practices across all mission areas.⁷²

⁷⁰ USMC, *Initial Capabilities Document for United States Marine Corps*, (August 1, 2011).

⁷¹ Naval Air Warfare Center Aircraft Division Public Affairs, "Department of the Navy goes green with Osprey," *Navair News*, www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=4730.

⁷² USMC, *Sustainability Plan 2011*, www.green29.org/Shared%20Documents/USMC_Sustainability_Plan_JAN_2011.pdf.

Goal 1 focuses on alternative fuels, emphasizing that the USMC is seeking to reduce its use of traditional fuels and increase its use of renewable energy sources on its installations. The sustainability plan states:

To reduce the amount of fossil fuels consumed by garrison mobile equipment and vehicles, the USMC is increasing the number and type of alternative fuel vehicles used at our installations. By breaking our dependence upon fossil fuels, the Marine Corps becomes a more sustainable and mission-ready force,” and “The reduction of GHG emissions goes hand-in-hand with employing energy strategies that conserve energy, reduce reliance on fossil fuels, and increase the use of renewables.”⁷³

The USMC’s alternative fuel efforts nests within the Navy’s stated goals for 50 percent of total Department of Navy energy consumption, which includes aircraft and surface platforms, to come from alternative sources. Use of alternative energy sources will also result in other benefits, such as GHG reduction, that will help the Marine Corps meet its relevant sustainability goals.

DoD AND MILITARY SERVICE DEMAND UPDATE

The Army, Air Force, and Navy set alternative fuel goals and targets that have implications for the quantitative demand for neat and blended operational biofuels that DLA Energy is responsible to procure. While previous studies, such as the FY10 NDAA Section 334 and DLA DORRA, have provided a foundation for these demand estimates, this study sought to update them with current baselines, projections, and assumptions. Understanding these projected operational biofuel quantity requirements is important to DLA Energy so it can plan and act to ensure that it is possible to procure these volumes, particularly at the economically competitive prices now required by all of the military services. The quantities are also significant in understanding the sustainability implications as the number of gallons becomes a multiplier for the sustainability assessment process (defines that magnitude of the sustainable supply chain risks).

We synthesized the current goals, targets, and their caveats to define and compile the needed baseline information. Working with DLA Energy and the military service control points, we obtained and confirmed the following baseline fuel use and projection data sets. As a baseline, each service’s goal uses a different frame of reference for the fuel use considered and the types of fuel included (Table 5-1).

⁷³ Combat Center Green Council, “Resources,” *Combat Center Green Council*, www.green29.org/Resources.aspx.

Table 5-1. Military Service Operational Biofuel Demand Types

Service	Applicable baselines	Fuel types	Neat or Blend
Army	Training installation consumption	Aviation and ground	Neat
Air Force	CONUS jet fuel consumption	Aviation	Blend
Navy ⁷⁴	Green Strike Group (2012/2016) and total Navy operational consumption (2020)	Aviation and marine	Neat

For the Army, we do not have a current peacetime baseline for training base aviation and ground tactical fuel use, due to combat deployments. As a proxy, we used the 2008 Defense Science Board report's 2007 Army peacetime petroleum estimate as an appropriate baseline for training base fuel over the next 10 years. We assume the training installation use does not change significantly over time, and our estimate assumes that the percentage is for neat biofuel, or 15 percent of the total in FY18, not that 15 percent of the total is a blend, which would only total 7.5 percent (Table 5-2).

Table 5-2. Army Operational Biofuel Demand Estimates (million gallons)

Category	2018	2019	2020
Army training base petroleum	214.0	214.0	214.0
Army alternative fuel goal (%)	15	18	21
Army alternative JP-8	16.1	19.3	22.5
Army alternative diesel	16.1	19.3	22.5

Note: The Army estimates for alternative fuel use have increased since the release of the AESIS and *Tactical Fuel and Energy Implementation Plan*. The FY10 NDAA Section 334 report applied the target percentage equally across fuels, but we have determined the Army uses more diesel than jet. This estimate uses the total fuel consumption against the target percentage.

For the Air Force, AFPA provided updated CONUS petroleum fuel consumption projections for the 2016 baseline—1.2 to 1.3 billion gallons of domestic aviation fuel use. The Air Force's alternative fuel use is assumed to grow in 2014 and scale up in 2025 toward the 2016 goal of 50 percent alternative fuel use. This 50 percent goal reflects blended fuel, so only 25 percent of the total volume represents neat fuel blend stock component (Table 5-3).

Table 5-3. Air Force Operational Biofuel Demand Estimates (million gallons)

Category	2014	2015	2016	2020
Total domestic aviation fuel use	1,250	1,250	1,250	1,250
Alternative fuel goal (% blended biofuel)	12.5	25	50	50
Air Force alternative fuel (neat)	78.13	156.25	312.50	312.50

⁷⁴ USMC projected demand is included within and supportive of the Navy demand quantities.

For the Navy, we engaged the Naval Supply Systems Command (NAVSUP) Energy staff concerning the amount of fuel necessary to fuel a Green Strike Group (160,000 barrels) and the estimate of total Navy tactical fuel consumption (672 million gallons). This covers both JP-5 for naval aviation and F-76 for surface ship purposes. To calculate the estimated alternative fuel usage, we assumed that the Green Strike would use a 50/50 blend, with a total requirement of 80,000 barrels of neat alternative fuel blend stock, or 1.68 million gallons of neat alternative jet fuel blend stock and 1.68 million gallons of neat alternative diesel blend stock (Table 5-4).

Table 5-4. Navy Operational Biofuel Demand Estimates (million gallons)

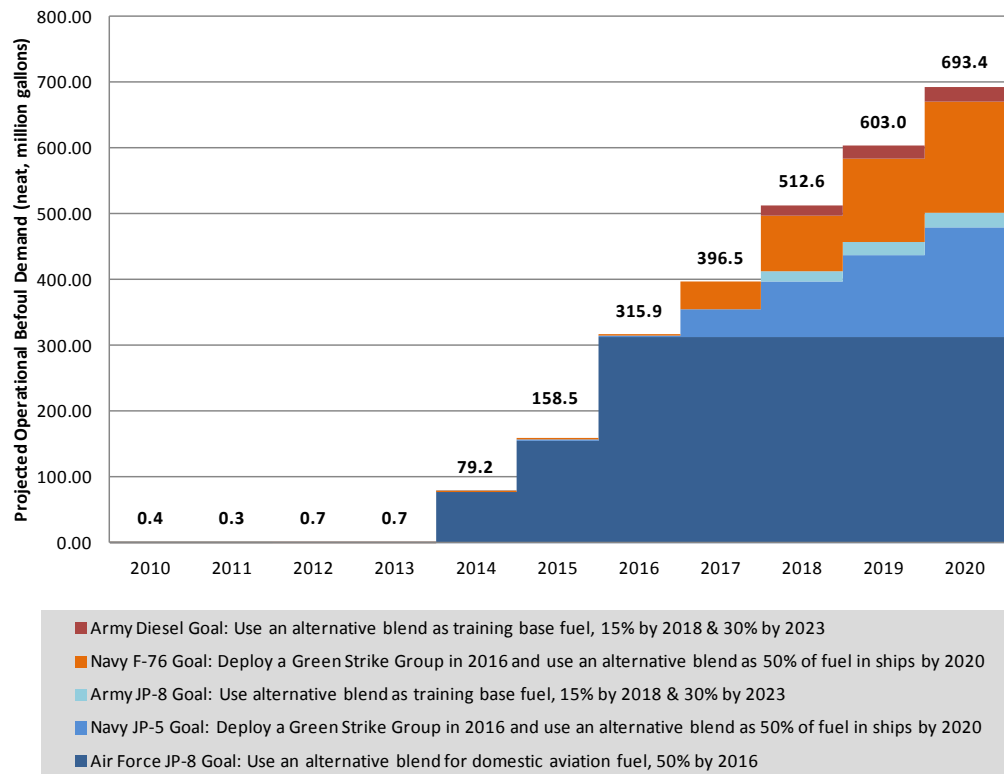
Category	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total petroleum use	Demo (900,000 gallons)		Green Strike Group (6.72 million gallons) ^a			Total Navy Tactical Fuel (672 million gallons)			
Alternative goal (%)	50	50	12.5	25	50	13	25	38	50
Navy alternative JP-5	0.1	0.1	0.42	0.84	1.68	42.0	84.0	126.0	168.0
Navy alternative F-76	0.35	0.35	0.42	0.84	1.68	42.0	84.0	126.0	168.0

^a The Navy estimates for alternative fuel use for 2016 goal have increased since the release of the "A Navy Energy Vision for the 21st Century." The NDAA FY10 Section 334 report assumed that 50 percent of the total fuel use of the group would be an alternative 50/50 blend. Subsequent communication with NAVSUP Energy revealed that the group would use a 50/50 blend for all operational fuels.

In each of these cases, we assume that the component of total fuel use subject to the services' goals remains constant over time in terms of total consumption. We also assume that unless otherwise specified, the allocation of alternative fuel is half for ground or ship diesel and half attributed to aviation jet fuel. We use the best available fuel baselines, but we do not make assumptions about fuel purchased from sources other than DLA or second guess the information provided by the respective service control points.

Using this approach and stated targets, we projected and updated the anticipated operational biofuel demand thru 2020 for JP-5/8 and F-76 alternative fuel requirements. The total estimated DoD demand for operational fuels grows from 0.6 million gallons of neat fuel product in 2012 to 693 million gallons by 2020 (Figure 5-2).

Figure 5-2. Operational Biofuel Demand (by Service), 2010–20
(million gallons)



Note: The service goal extrapolated fuel quantities represent neat, rather than blended, fuel.

Operational alternative fuel demand of the military services is comprised of the drop-in biofuel equivalents of F-76 (marine diesel) and JP-5/8 (jet fuel). The demand for drop-in biofuels continues to increase in FY13. Qualified alternative jet fuels that can meet this requirement is currently limited to F-T SPK and HEFA fuels as specified in the annexes of ASTM International D7566. This re-emphasizes the need for the current military and civilian efforts to characterize, test, and certify platforms and issue new annexes for additional ATJ, CRJ, and other synthetic biofuel pathways so as to better expand the available alternative fuel options and ensure sufficient drop-in biofuel availability in the marketplace.

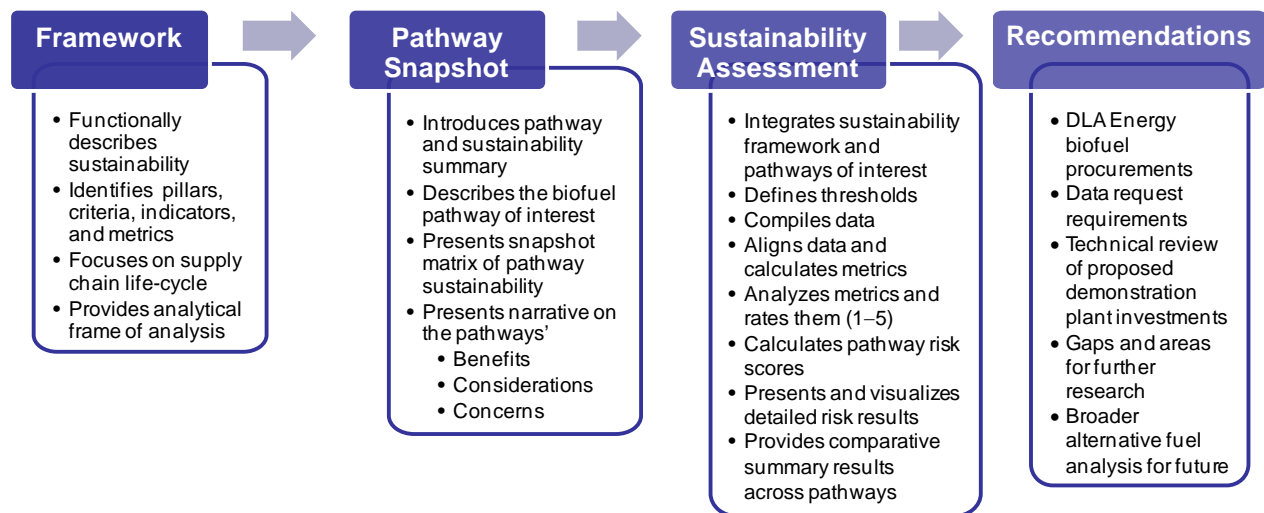
Chapter 6

Biofuel Sustainability Architecture

With the military services' projected demand for alternative fuel products and their sustainability drivers, DLA Energy is being called upon to procure significant quantities of drop-in biofuel products, provide SME input, and perform technical due diligence reviews in support of operational demonstrations and the DPA. DLA is also being asked (explicitly or implicitly) to consider the sustainability aspects and understand the upstream supply chain risks.

To assist DLA Energy, LMI developed a customized biofuel sustainability architecture that consists of a framework, a pathway context, and the means to quantify biofuel sustainability using metrics (Figure 6-1).

Figure 6-1. Proposed Biofuel Sustainability Architecture



In addition to identifying and quantifying metrics, this architecture was developed with DLA Energy to provide a consistent but flexible way to

- ◆ frame sustainability;
- ◆ summarize and detail the biofuel feedstock and conversion pathway of interest and its sustainability benefits, considerations, and concerns;
- ◆ assess and visualize individual pathway's sustainability risks; and
- ◆ recommend ways to directly support DLA Energy business processes for biofuels procurement, due diligence technical reviews, and R&D need identification.

This proposed architecture consists of four components:

- ◆ *Framework*. Furnishes a consistent context for the evaluation of biofuel feedstocks and conversion pathways. Defines key terms, such as pillars, criteria, indicators, and metrics; lays out a consistent sustainability hierarchy; and identifies the policy and industry relevance of each of the sustainability indicators and metrics.
- ◆ *Pathway snapshots*. Summarize biofuel pathways and their sustainability attributes, describe the feedstock and conversion pathway of interest, and qualitatively discuss the pathway's sustainability benefits, considerations, and concerns.
- ◆ *Sustainability assessment*. Captures the needed quantitative data and qualitative inputs; analyzes and categorizes these inputs to identify sustainability hazards, consequence sensitivities, and mitigations in each life-cycle stage and total; and presents these supply chain risks individually and comparatively across several different pathways.
- ◆ *Recommendations*. Applies individual and comparative biofuel pathway assessment results, insights, and findings to inform DLA Energy roles, business processes, and decision making.

SUSTAINABILITY FRAMEWORK

What is biofuel sustainability? More to the point, what is sustainable biofuel? To effectively develop biofuel sustainability metrics, we examined these definition and scope issues, which Joint Publication 1-02 does not cover.

In our first team meeting with DLA Energy, we sought to define the initial sustainability framework for analysis that would inform the remainder of the work plan. Although the criteria identified in the performance work statement (PWS) and the conceptual definition provided in the SSPP offered a starting point, DLA Energy was not prescriptive and quite flexible in defining sustainability. It did, however, emphasize that our approach should integrate with applicable federal drivers, comport with OSD and military service policies and strategies, and align with emerging industry standards and best practices as found in the literature.

Definitions

Following the initial literature review, we noted great diversity—even in the conceptual definition and use of basic terms such as pillars, criteria, indicators, and metrics—throughout policy documents, indicator studies, and certification frameworks. The DLA Energy PWS gives guidance on metrics and basic criteria, but our team had to draw from broader government research literature, particularly that of the DOE national laboratories, to select working conceptual definitions for framework, pillars, criteria, indicators, and metrics terms and their use.

For this study, we define these terms as follows:

- ◆ *Framework* is the basic conceptual structure used to consistently assess the individual or relative sustainability of a given biofuel.
- ◆ *Pillars* are the foundational principles and groupings within a given sustainability framework, which may include operational, economic, environmental, and social aspects. Each pillar comprises one or more criteria.
- ◆ *Criteria* are secondary categories within a pillar that describe resources, media, capacities, or other attributes across the applicable steps of a biofuel life-cycle. Criteria comprise one or more indicators.
- ◆ *Indicators* are specific gauges of performance, impact, and supply chain risk for a given criterion. One or more quantitatively or qualitatively defined metrics may be used to assign values to an indicator.
- ◆ *Metrics* are the measurable characteristic, impact, or risk mitigation attributes of a particular indicator.

In general, we apply these indicators and metrics terms as part of a supply chain risk management approach and incorporate SMART (specific, measurable, actionable, relevant, and timely) attributes to the extent possible.

Hierarchy

Within this construct, LMI generated a high-priority indicator list across all pillars using the hybrid crosswalk approach detailed in Chapter 2. The resulting list of criteria and indicators was unwieldy and was first prioritized by relevance. DLA Energy provided additional input, focusing on certain indicators, particularly those in the environmental pillar (the “green baker’s dozen”). The proposed high-priority indicator hierarchy (Table 6-1) requires a broader review by DLA Energy leadership, validation using the aforementioned SMART attributes, and finalization to guide the future development of the sustainability architecture. The remaining medium-, low/medium-, and low-priority indicators can be added and integrated as staff time, resources, and technical data become available.

Table 6-1. High-Priority Biofuel Sustainability Pillars, Criteria, and Indicators

Pillars	Criteria	High-priority indicators
Operational	Suitability	Fuel readiness level
		ASTM specification met
		Military fuel specification met
	Energy security	Improve fuel properties
		Energy diversity

Table 6-1. High-Priority Biofuel Sustainability Pillars, Criteria, and Indicators

Pillars	Criteria	High-priority indicators
	Availability	Net energy balance/efficiency
		Fossil energy use/depletion
		Feedstock readiness level
		Feedstock/fuel production capacity
		Production timetable
Economic	Viability (PWS 3.2.3)	Distribution/transportation constraints
		Scalability
		Production cost and price
		Project viability
Environmental	Water (PWS 3.2.2)	Sustainability practices are norm
	Air (PWS 3.2.4)	Water quantity
		Water quality
		Air quality
	Land use (PWS 3.2.1)	Ozone depletion
		GHG—direct emissions
	Soil	Land use—direct
		Soil quality
	Productivity	Soil quantity
		Nutrient requirements/fertilizer use
	Waste	Pesticides use/management practices
		Solid waste
	Biological resources (PWS 3.2.5)	Hazardous waste
		Invasive species
		Threatened and endangered species
		Biodiversity impacts
Social	Food security	Genetically modified organisms
	Quality of life	Food security—direct
		Job creation
	Safety and health	Economic prosperity
		Public health
Sustainability (PWS 3.2.6)	(Aggregate)	Legal and institutional compliance
		Transparency
		Public outreach
		(Aggregate)

PATHWAY SNAPSHOTS

The framework defines and frames sustainability in a hierarchy of related pillars, criteria, and indicators. To complement the framework, we summarize and detail the biofuel pathways of interest and their sustainability benefits, considerations, and concerns.

During the literature review and analysis, we examined EPA's draft and final *Biofuels and the Environment: First Triennial Report to Congress* to identify relevant methods and information.^{1,2} This report describes the current and potential environmental impacts from first-generation feedstocks (corn starch and soybeans) and second-generation feedstocks (corn stover, perennial grasses, woody biomass, algae, and waste) and the resultant biofuels (conventional and cellulosic ethanol and biomass-based diesel).³ One figure in the *draft* report shows a qualitative overview, based on EPA's best professional judgment, of the maximum potential range of domestic environmental and resource conservation impacts associated with per-unit-area production of the feedstocks discussed, while another identifies impacts associated with production, transport, and storage of ethanol from corn and cellulosic feedstocks and biodiesel from soybeans. An appendix summarizes the information that served as a basis for the figures, but the *final* report uses a different tabular format to highlight impact categories.

We adapted EPA's original matrix approach and developed a biofuel pathway snapshot template that consists of the following:

1. Pathway summary and sustainability matrix
2. Pathway detailed description
3. Key pathway sustainability considerations
4. Sustainability benefits, considerations, and concerns.

(See Appendix A for snapshot examples.)

Pathway Summary and Sustainability Matrix

Each pathway snapshot contains a one-page summary of the pathway and its sustainability, including a brief introduction and a graphical representation of the fuel

¹ EPA, Office of Research and Development, National Center for Environmental Assessment, *Biofuels and the Environment: First Triennial Report to Congress, External Review Draft*, EPA/600/R-10/183A (Washington, DC: January 2011).

² EPA, Office of Research and Development, National Center for Environmental Assessment, *Biofuels and the Environment: First Triennial Report to Congress*, EPA/600/R-10/183F (Washington, DC: December 2011).

³ Ibid.

life-cycle from feedstock products, to conversion, to fuel use. The pathway's sustainability attributes are discussed to preface a pillar-level summary matrix.

Pathway Detailed Description

The snapshot then details the biofuel pathway throughout its life-cycle. After presenting a more technical pathway diagram, this two-page section elaborates on the initial pathway introduction and details each of the five life-cycle stages:

1. Feedstock production (feedstock cultivation and harvest)
2. Preprocessing and logistics (transport, storage, and preprocessing)
3. Biofuel production (conversion of feedstock or intermediate material into biofuel)
4. Biofuel distribution (handling, blending, transport, and storage)
5. Operational use (vehicle fueling and operation).

In a simplified format, these detailed descriptions identify feedstocks cultivated, fuel intermediates, processing and production techniques, neat (unblended) fuels, and end product operational biofuels.

Key Pathway Sustainability Considerations

This detailed matrix expands on the summary matrix (which presented sustainability considerations at the pillar level), introducing criteria-level sustainability considerations. This matrix details the benefits, considerations, and concerns of the biofuel pathway described.

Sustainability Benefits, Considerations, and Concerns

The final section builds on the detailed sustainability matrix to describe, analyze, and substantiate (by pillar and criterion) the benefit, consideration, or concern assessment for each rated criterion. It may, in some instances, provide supplemental information or examples to illustrate or explain the impacts. Not a comprehensive analysis, it concisely explains key sustainability benefits, considerations, or concerns associated with a pathway and explored further in the sustainability assessment.

SUSTAINABILITY ASSESSMENT

The sustainability assessment is at the heart of the biofuel sustainability architecture. The draft framework functionally defines sustainability, and the snapshot provides the context by identifying a biofuel pathway of study. The sustainability assessment—a risk management-based process—produces hazard, consequence,

mitigation, and, ultimately, risk ratings. It will evolve to incorporate emerging priority indicators reflecting new questions, data, and analytical findings. The proposed sustainability assessment features

- ◆ a risk management approach,
- ◆ an indicator technical sheet, and
- ◆ a four-step process.

Risk Management Approach

Other organizations—including GBEP, ORNL-CBES, and CAAFI-FAA—have made worthwhile, robust efforts to list indicators and metrics for assessing biofuels’ sustainability. Without common units, however, these indicators and metrics will lack relevance in their application for procurement decision making, due diligence review, and prioritizing information gaps. On the basis of its widespread practice and demonstrated utility across the DoD and National Aeronautics and Space Administration (NASA) acquisition and supply chain communities, we found risk management an appropriate and advantageous approach for DLA Energy purposes in the alternative fuels context.

A sustainable supply chain risk management approach for biofuel feedstock and conversion pathways is a highly appropriate extension of existing best practice and complements the three-level analysis commonly used in LCA.⁴ LMI previously integrated these disciplines when developing GreenSCOR, so our proposed approach builds on these prior innovations. First, a supply chain risk management approach directly relates to and supports DLA Energy’s executive agent role of procuring operational fuels. Second, it can draw on standard practice in the supply chain community and is well suited for the analysis of diverse upstream activities and their life-cycle impacts. Third, the extension of this widely used management practice will help enable proactive and consistent sustainability assessments of next-generation biofuels—particularly for product procurements and due diligence reviews of regional demonstrations or facility proposals—and inform future R&D efforts. For example, this study’s initial findings on life-cycle GHG approaches identified a gap in marine diesel analysis,⁵ which is now being addressed through collaborative interagency efforts, given this fuel’s significance to Navy operational energy.

For these reasons, we propose the extension of supply chain and ESOH risk management approaches as applied in numerous other settings. These settings include

⁴ Taylor Wilkerson, “Governing Tangible Risk: The SCOR [Supply Chain Operations Reference] Model,” *X-SCM: The New Science of X-treme Supply Chain Management*, 1st ed. (New York, NY: Routledge, 2011), 95–104.

⁵ Early in the study, discussions with ORNL and EPA’s OTAQ indicated that marine diesel pathways were not being researched or analyzed. The lack of LCA on F-76 fuel was brought to DLA Energy’s attention, and this gap was addressed in the interagency research plan.

DoD acquisition (MIL-STD-882E) and logistics processes, civilian facility and installation management and sustainability, NASA continuous risk management (CRM), and EPA ecological risk management. Leveraging the language of risk will facilitate clearer communication within DLA Energy's business processes, across DLA corporately, with DoD, and with federal partners like FAA, DOE, and USDA that may utilize CRM. This approach will help DLA Energy robustly frame, assess, and manage issues of concern, using the following concepts:

- ◆ Likelihood (probability of supply chain hazard) = feedstock and conversion pathway characteristics.
- ◆ Consequence (severity of supply chain impacts) = regional- or site-specific conditions or relative sensitivities.
- ◆ Mitigation (of the supply chain risk) = plans, technologies, or practices to manage or reduce the raw risk.

We begin with the indicator technical sheets, analyzing identified indicator metrics to determine relevance, feasibility, category placement, and utility within a given risk management category. We then obtain metric data sources, compile them, and evaluate them for life-cycle stage applicability and overall technical feasibility. In the case of quantitative input, thresholds have been identified or synthesized to yield standardized measures for likelihood, consequence, or mitigation values. From earlier outreach efforts, we consult with technical SMEs and collaborating organizations identified in the indicator technical sheet to review and advise on their refinement, to the extent possible.

We then analyze the resulting likelihoods and consequence metrics and assign numbers 1–5 using metric specific thresholds. Using the schema in Figure 6-2, we assign raw risk values from 1 to 25, which can then be used as inputs for prioritization, management decisions, and resourcing. These raw risks can be accepted “as is” or mitigated further to reduce their likelihood or consequence ratings. Uncertainty should be factored into such assessments and explicitly documented. If mitigated, a new adjusted risk prioritization value results and the CRM process could continue until it is acceptable or eliminated. We note any gaps identified and incorporate priority metrics into future research plans to develop new data or emerging analysis methods.

Figure 6-2. 5 × 5 Risk Matrix Example

L I K E L I H O O D	5	7	16	20	23	25
	4	6	13	18	22	24
	3	4	11	15	19	21
	2	2	8	10	14	17
	1	1	3	5	9	12
		1	2	3	4	5
		CONSEQUENCE				

Indicator Technical Sheets

One of the greatest challenges in all performance metrics efforts is balancing relevance, coverage, and utility. We identified many potential indicators, but developing them required prioritizing criteria and indicators on the basis of time and available resources. DLA Energy asked that we first focus our indicator and metrics development efforts on the environmental sustainability pillar’s “green baker’s dozen” of high-priority indicators. We also addressed production cost/price and food security per the PWS requirements.

We developed a standardized template that defines the “what” and captures the “who” and “how” aspects applied to a biofuel life-cycle. Our study team reviewed existing biofuel standards, reporting protocols, and sustainability assessment efforts to identify key elements and content. We leveraged these inputs to develop a consistent approach and template that include

- ◆ indicator description;
- ◆ relevance and rationale;
- ◆ metrics selected;
- ◆ measurement and analysis approach;
- ◆ resources, SMEs, and capabilities; and
- ◆ references.

After defining the indicator, we used a statutory and policy crosswalk analysis to generate input concerning its relevance to statutes, policy, federal frameworks,

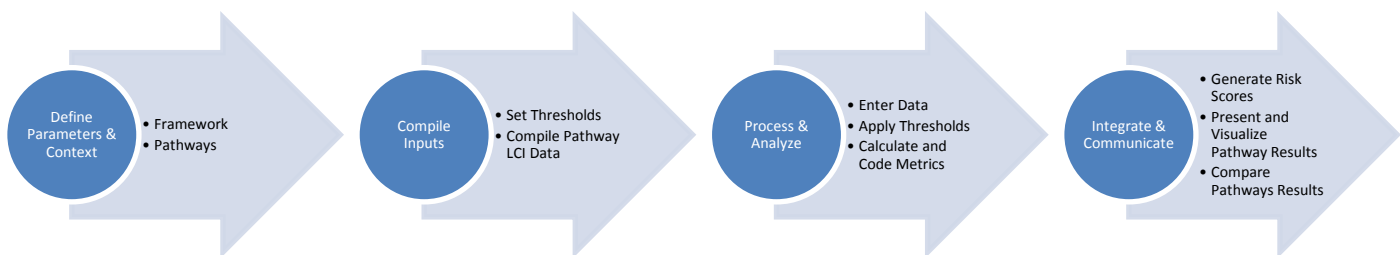
and industry standards (answering the “So what?” question). From there, we identified constituent metrics (using findings from the previously analyzed biofuel sustainability standards, frameworks, and SME interviews) and then categorized them using the risk management approach. We described each metric and furnished instruction on its measurement and analysis, highlighting resources, SMEs, and capabilities to enable follow-up engagement and support, as necessary. Each indicator technical sheet documents the application of SMART principles, identifies the measurable sustainability metrics, and includes the analysis “how to” for the metrics, data sources, calculations, and thresholds.

(Appendix B contains the indicator technical sheets developed in the course of this study.)

Sustainability Assessment Process

Building on the foundation of the indicator technical sheets and risk management approach, the sustainability assessment, a four-step process, integrates and generates this multi-objective analysis result. Figure 6-3 illustrates the proposed steps and their constituent pieces.

Figure 6-3. Sustainability Assessment Process



(Appendix C contains representative screenshots of example pathway sustainability assessment in Microsoft Excel workbook form.)

DEFINE PARAMETERS AND CONTEXT

This first step largely documents and revises the current understanding of the framework and pathway snapshots. We review and capture the sustainability framework used at the time of the assessment, documenting the criteria, indicators, and metrics available and applied for the assessment. The framework presents the scope of the analysis, and the pathway snapshot captures the current universe of feedstock and conversion pathways that apply to operational fuels.

COMPILE INPUTS

The indicator technical sheets provide the foundation for the sustainability assessment process. They first identify the indicators and metrics of interest to DLA Energy and organize them in categories of likelihood, consequence, and mitiga-

tion. These are the organizing categories used to structure the risk management process. The indicator technical sheets specify the analytical thresholds developed for the Level III analysis for each identified indicator metric. They list the data and LCI sources identified. The sustainability assessment workbook accepts both LCI inputs and analysis thresholds.

PROCESS AND ANALYZE

Once the specific pathway data are input, they are pulled into respective indicator analysis sheets. Each indicator's respective threshold levels are pulled into these worksheets and applied against an element of the life-cycle stage and in total for each of the pathways being analyzed. These macros categorize the data inputs and generate likelihood, consequence, and mitigation scores of 1 to 5, as appropriate. Each indicator worksheet calculates these ratings for each pathway analyzed, where data are available. These analysis worksheets capture the detailed data across life-cycle stages 1 through 5 for each indicator metric and their resultant life-cycle ratings.

INTEGRATE AND COMMUNICATE

Indicator and metric scores alone do not reflect complete sustainability assessment. They must be reintegrated using the documented sustainability framework. The sustainability assessment workbook is structured to enable consistent reintegration of analysis results and generates metric ratings in detailed and summary forms to best serve the DLA Energy end user and purpose. In addition, individual results are presented in color-coded tables, and these individual pathway report sheets will include bar chart and radar diagram visualizations of the results. Leveraging these individual pathway results and visualizations, the sustainability assessment then provides a comparative summary assessment and visuals to effectively communicate sustainability assessment results across multiple pathways.

RECOMMENDATIONS

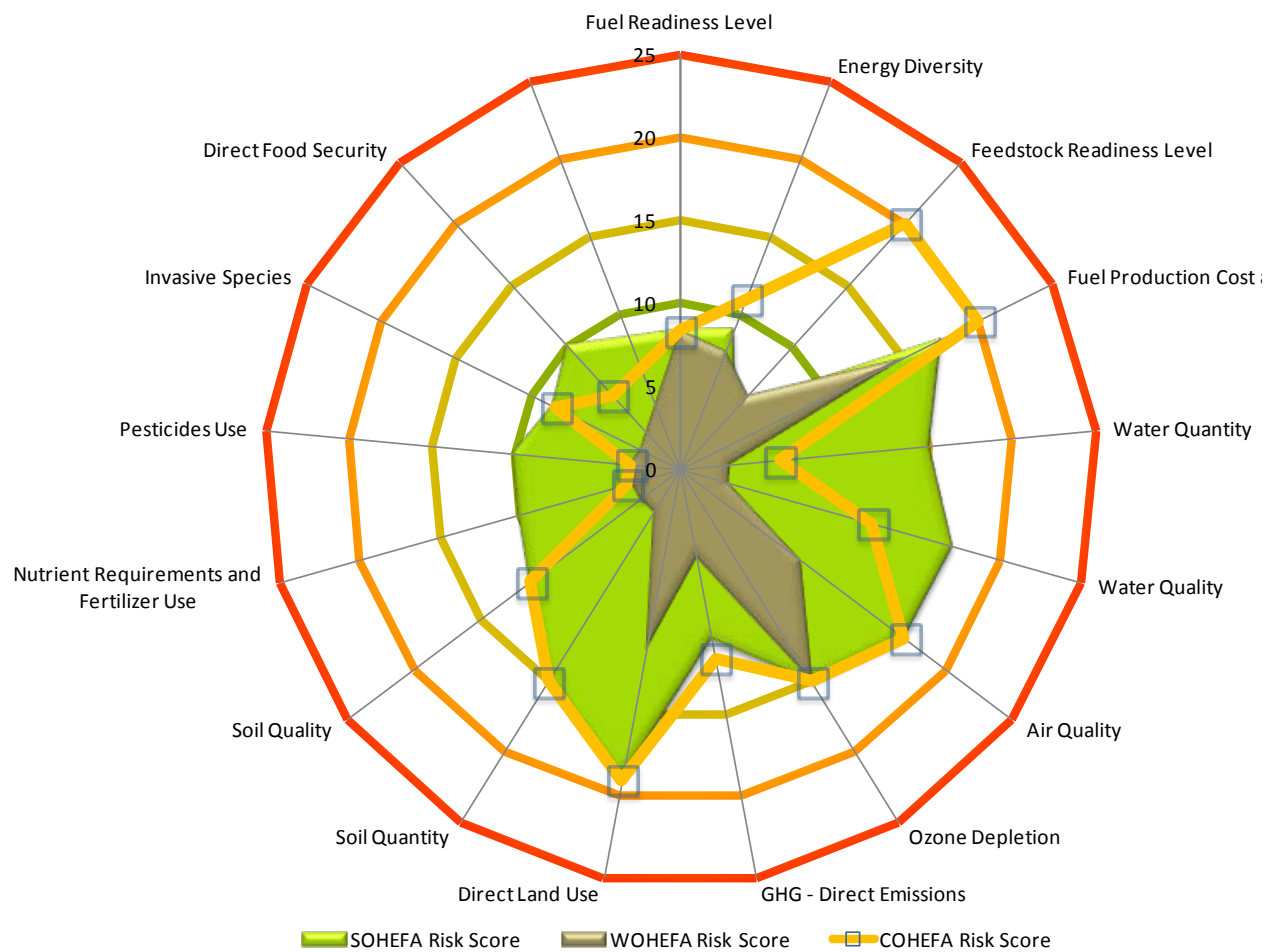
Detailed as it is, the sustainability assessment only represents the compilation, organization, analysis, and presentation of results. To become actionable, it must first effectively communicate the analysis, uncertainties, and caveats. These outcomes need to be relevant and integrated into the respective DLA Energy CRM process. Ultimately, these contextualized results must generate actionable advice or recommendations for operational biofuel procurement, technical review, or gap identification.

Assessment Result Communication

The sustainability assessment process streamlines the assessment of biofuel sustainability indicators, organizes the analysis, and generates consistent yet

transparent results. It also generates various assessment communication mechanisms to make these results more accessible. For DLA Energy users interested in procurement, the workbook’s individual pathway sustainability summary and visualizations offer easier access to the sustainability assessment and analysis that applies to a particular solicitation response. For due diligence technical reviews, the individual pathway detailed summaries can serve as a resource, with more nuanced data by life-cycle stage. When comparing multiple biofuel pathways and offerings, both of these roles are supported with multiple means to communicate risk ratings in tabular, color-coded, and various graphic forms (Figure 6-4).

Figure 6-4. Comparative Assessment of HEFA Pathways (Notional)



DLA Energy’s need for gap analysis can draw lessons from the sustainability assessment process itself as well as the missing data identified through the process, whether from the analysis sheets, individual detailed summaries, or multiple pathway comparisons.

Supply Chain Sustainability CRM

The sustainability assessment process can certainly yield ad hoc conclusions and recommendations to meet current needs, but it will not realize its potential or yield a good return on investment for DLA Energy decision makers unless the proposed architecture and processes are integrated into DLA's management processes. From our literature review and analysis,⁶ we propose the adoption of a CRM-based approach as used in DLA and federal supply chain management and sustainability programs. Not only is this approach used by and compatible with current DoD and federal sustainability efforts, but it can build on best practices for supply chain management, such as SCOR and GreenSCOR.

The results and recommendations will be SMART and consistent. Moreover, the CRM paradigm and language increase its transparency and communication effectiveness should procurements or technical reviews require external review or audit. Finally, further development and sustainment of this sustainability architecture will require internal DLA Energy support as well as ongoing external partnerships with other federal agencies. Adopting this architecture under these auspices can help make the case internally and complement the priorities of these necessary external collaborators.

⁶ Taylor Wilkerson, "Supply," *Climate Change: What You Can Do Now*, (McLean, VA: LMI, March 30, 2012). www.lmi.org/climatechangebook.

Chapter 7

Recommendations and Conclusion

This study's charge was to build the foundation for an operational biofuel sustainability architecture that helps DLA Energy (1) meet military service demand for such fuels, and (2) do so in a manner that supports achievement of DoD and federal government sustainability goals. Military operational effectiveness (operational sustainability) is the priority, which is undermined when decisions do not consider the economic (including fiscal), environmental, and broader social criteria, particularly when they represent upstream supply chain risks. DLA Energy's foresight has positioned it to influence the numerous (but fragmented) federal efforts in this area and inform its partners in commercial aviation via the CAAFI environmental progression. In short, the mission imperative to meet the military service's demands helped focus this research effort on practical ends in meeting DLA Energy's client roles.

In this final chapter, we present our recommendations for utilizing, integrating, and maturing the proposed biofuel sustainability architecture. First, we briefly address the proposed sustainability architecture's utility in helping DLA Energy fulfill military service requirements for operational biofuels. Second, we discuss the architecture's use of "best-value tradeoff" contracting and supply chain CRM, including steps for integrating them into DLA Energy business processes. We then discuss the internal DLA, DoD, and interagency vetting and partnering needed to mature the sustainability architecture moving forward. We examine the need for broader discussion on acquisition policy and practice alignment within DLA and across the interagency, such as with the General Services Administration (GSA). We discuss refining future sustainability assessments through data package requirements or "outsourcing" such efforts through standards and certifications as the industry matures. We conclude by briefly describing this study's contribution toward achieving DLA Energy goals.

ARCHITECTURE SUPPORT FOR DLA ENERGY NEEDS

This study primarily focuses three DLA roles:

- ◆ Operational biofuel procurement best-value tradeoff evaluations
- ◆ Demonstration or production facility proposal technical reviews
- ◆ R&D needs identification, prioritization, investments, and partnerships.

The proposed sustainability architecture directly focuses on supporting the first two roles, and the last is additional value added output coming out of the sustainability assessment step.

In support of *best-value tradeoff procurement activities*, we recommend initially using available Level III LCI data as inputs and calculating only likelihood and mitigation metrics (Appendix B) as part of the sustainability assessment. This application focuses on the feedstock and conversion pathway characteristics to provide macro-level metrics that can be consistently compared with other drop-in biofuel offerings. As discussed, the sustainability assessment supports the use of an IGSA, an expansion of current procurement tools, such as the IGCE. Used in this context, the metrics and processes are set up similar to the CAAFI draft environmental progression and have been coordinated with it for consistency with commercial aviation industry driven efforts.

This procurement role is a key application of the proposed sustainability architecture, but DLA Energy required a more comprehensive process to help perform *due diligence technical reviews of proposed production facilities* investments. For example, DLA Energy personnel have been important technical advisor and review resources during the DPA Title III effort. We recommend a sustainability assessment process, indicator technical sheets, and metrics-based risk management approach designed to accommodate technology characteristics (likelihood and mitigation) and account for the regional sensitivities or even local conditions (consequences) among the different producer proposals.

Given the DoD and federal stake in such projects, the due diligence review is structured flexibly to allow quick-screening, Level III analyses down to supply-chain-specific Level I LCAs. This analytical flexibility allows assessment of risk level, investment stake, or prioritized technical assessment resource constraints. Furthermore, while an initial Level III sustainability assessment can be a rough first cut and inform initial down-selections, it can be augmented and updated as more detailed data becomes available on the specific value chain. Inherent in the proposed approach is the best practice of CRM, which will keep the sustainability assessments from becoming stale and outdated as the industry matures and uncertainties are reduced.

These are DLA Energy's primary applications for the proposed architecture, but the process of going through the sustainability assessment will also help identify data gaps (where no data are available or high uncertainty is noted). We recommend that DLA Energy use this knowledge to *identify needs and prioritize its R&D program*. Just as important, we suggest that DLA Energy use it to help define and contribute the most pressing research questions to its federal interagency partners. During this study, pressing application questions led to valuable discussion with other agencies, including USDA, DOE, and EPA, on their biofuel research programs, even helping to spur action to answer the questions, such as the absence of marine diesel pathways in DOE's GREET1_2011 model. These circumstances suggest that DLA Energy's sustainability assessment process can

furnish important input for agency partners in framing their questions and finding answers, which could ultimately serve DLA purposes, the military services' needs, and our Nation's interests.

INTEGRATION WITH DLA BUSINESS PROCESSES

DLA Energy required a fuller awareness of the sustainability criteria for these emerging operational biofuels. Their feedstocks and production pathways present novel upstream sustainability benefits, considerations, and concerns not previously considered in procuring traditional petroleum-based, commodity fuels. As the military service demand for new biofuels has grown and DoD increasingly engages this maturing market, DLA Energy saw the need for biofuel sustainability metrics and architecture in which to evaluate biofuel opportunities, risks, tradeoffs, and uncertainties. We developed this architecture and aligned it to serve DLA Energy applications and roles, but it will only have limited utility or relevance if it is not integrated into business processes.

The proposed sustainability assessment can yield useful ad hoc comparisons and conclusions, but it will not realize its potential or yield a good return on investment for DLA Energy decision makers if the processes and architecture are not integrated into DLA's risk management and decision making. We thus recommend that *DLA Energy initiate an internal, agency-wide discussion on sustainability assessment* and its integration with DLA business processes (we discuss interagency and product area coordination later). We propose an architecture based on the continuous improvement approach already used by DLA, in federal supply chain management, and even in some institutional sustainability programs. The CRM approach used by and compatible with current DoD and federal sustainability efforts can help DLA achieve Goal 7, *Sustainability Practices Become Norm* in its *Strategic Sustainability Implementation Plan*.

Sustainable acquisition, product procurement, and metrics mandates govern installation fuels, nonfuel commodity products (paper, computers, etc.), and fleet vehicles and their fuels, but weapons platforms and their operational fuels have been exempt from both EO and statutory requirements. This leaves operational biofuel sustainability metrics and their use unencumbered by the numerous performance goals, reporting mandates, and certification schemes covering most of these other products. The sustainability architecture's integration into DLA Energy business processes can be planned to maximize utility, effectively support internal decision making, and best serve the military services' needs. This situation reemphasizes the importance of vetting the proposed sustainability architecture internally and across DLA Energy to skillfully plan and implement its integration adoption, and use

INTERNAL ENGAGEMENT AND EXTERNAL PARTNERS

The proposed sustainability architecture and its components are a foundation, but they are not finished or production ready. In many ways, their evolution will by necessity mirror the maturation process of the advanced biofuel industry. This internal DLA Energy development process will need to continue beyond the scope of this task, yet the burden need not be borne by DLA Energy alone. The development and eventual maintenance of this sustainability architecture will require internal DLA Energy support and ongoing partnerships with other federal agencies and industry.

DLA Energy now has a foundational architecture, a framework, processes, and examples of how the sustainability of biofuel feedstock and conversion pathways can be assessed. However, this internal capability will only hit the high-priority sustainability indicators and cover a handful of advanced biofuel pathways. It gives DLA Energy staff members an initial ability to inform their identified roles, but it does not yet represent a production-ready architecture because it needs to be integrated with business processes. Furthermore, it must engage OSD and the military services on their sustainability priorities and partner with other agencies on data and analysis capabilities.

We recommend that DLA Energy engage DLA, military service, and OSD stakeholders to *vet the proposed sustainability architecture* and build support, prioritize indicators, and broaden ownership. The framework is purposefully integrated with these stakeholders' respective mandates, strategies, and implementation plans to aid in this effort. We suggest a *three-step engagement and review process*:

1. Brief DLA leadership on the proposed biofuel sustainability architecture.
2. Give this report to OASD (OEPP) for review and to recommend military service stakeholders for distribution.
3. After incorporating the reviewer comments, engage these OSD and military service stakeholders to rank the remaining indicators and develop an out year work plan.

If these stakeholders express a particular interest or urgency, consider their priorities and discuss collaboration options, particularly if they have resident expertise or resources to support the architecture's accelerated maturation.

Partnering opportunities are, however, not limited to the military services and OSD. This study's interagency outreach has clearly emphasized the need for technical collaboration and data sharing and revealed a keen agency interest in meeting DLA Energy's technical review and decision-making needs in regard to alternative and advanced biofuels. Other federal agencies—particularly those with a mission-related stake in bioenergy, agriculture, energy, or the environment—

have already shown substantial interest, due to the integrative yet focused scope of our study's aims. The broad challenge is fragmented agency programs and efforts, and the opportunity is the pressing need to facilitate focus on key questions, data needs, and LCI sharing. We first recommend that DLA Energy representatives annually *brief identified data gaps and analysis uncertainties to the Biomass Research and Development Board*.

DLA Energy's finite staff and resources limit its ability to develop the data sets, broad integration, and analysis to support a sustainability assessment process for all biofuels. Either the coverage and depth will fall short or the results will be achieved long after they are needed. Therefore, we recommend *DLA Energy further cultivate interagency relationships and agreements to provide targeted data, analysis, and SME reviews* for biofuel sustainability assessments.

As a third yet key step, DLA Energy may wish to influence and guide the emerging interagency dialog—among USDA, EPA, and DOE—on establishing a biofuel life-cycle data-sharing network. DLA Energy would then have the opportunity to influence this data-sharing network's content and format, particularly by contributing practical data call templates (like those developed with ANL during this study). Doing so will help ensure the DLA Energy team has a seat at the table, making the interagency data-sharing network's outputs relevant and usable in DLA Energy's sustainability architecture moving forward.

We recommend *DLA Energy spearhead the interagency dialog on the biofuel life-cycle data-sharing network* to better enable biofuel sustainability assessments of new pathways or streamlining future updates to current assessments. Given a quickly maturing biofuels industry, the updated indicator data may represent important new knowledge (high feedstock yields, greater energy efficiency, and less GHG emissions) that impacts DLA Energy's internal supply chain risk management and procurement decisions. Doing so may not only help ease the analysis burden on the DLA Energy staff but also complement the priorities of these necessary external partners.

To implement this recommendation, we suggest that DLA Energy brief this need and opportunity to the existing IAWG on Alternative Fuels. DLA should request that a subgroup be established to discuss requirements and to develop a work plan toward realizing a biofuel life-cycle data-sharing network. Priority discussion topics might also include the establishment of an interagency review board to coordinate and assist with interagency biofuel pathway assessments, particularly those that can inform DLA Energy's internal supply chain risk management and procurement decisions.

ALIGNING POLICY AND STRATEGY

Another priority topic within the IAWG on Alternative Fuels might be the key challenge of fragmentation among “green” procurement programs, such as affirmative procurement and biopreferred, and sustainable acquisition policies,

programs, and requirements. This study found a smorgasbord of procurement mandates and strategies, technical review options, and second- or third-party certifications. Informal dialogs may elicit interagency guidance, lessons learned, and best practices, such as GSA Section 13 supply chain data collection, DLA green procurement, and product sustainability certifications.

We suggest *DLA Energy informally engage other DLA business lines and GSA in a discussion of their use of Federal Acquisition Regulation (FAR) provisions, green procurement strategies, and sustainable acquisition policies*. DLA green procurement program and strategic sustainability implementation plan activities can render insights that DLA Energy can apply to and integrate in the proposed sustainability architecture and existing business processes in conformance with DLA policy, strategies, and goals. Interagency discussions with the GSA-led Section 13 working group could include the GHG data request strategy and GSA lessons learned regarding the use or endorsement of federal standards and third-party sustainability certifications. DLA Energy can build on these informal discussions concerning the FAR, best-value tradeoff procurement, data request strategies, and options for future certification use. However, given evolving statutory and interagency guidance, it seems premature for DLA Energy to accept or endorse a particular biofuel standard or certification system, particularly as they are still evolving or being adapted to the United States.

We recommend that *DLA Energy utilize and further develop the proposed sustainability architecture* to manage biofuel sustainable supply chain risks. The proposed framework captures 80 to 90 percent of the criteria and indicator areas present in many of the existing feedstock and biofuel sustainability certifications systems. In addition, it can provide DLA Energy with initial sustainability assessments while enabling a detailed product supply chain analysis, which can eventually lead to voluntary certification by vendors. However, in the near term, the DLA staff would need to perform the sustainability assessment review as a limited IGSA (demonstrating Section 526 compliance, priority service requirements for water, food, etc.).

In the midterm, we suggest a *phased approach for considering vendor data package requirements, second-party standards, or third-party biofuel sustainability certifications*:

1. Require biofuel producers to furnish detailed data packages for streamlining internal assessment and continuously addressing knowledge gaps.
2. Start with data package requirements and phase in voluntary standards or certification components as the industry matures.
3. Encourage, endorse, or ultimately require standards compliance or certification statements or third-party program participation as part of procurements.

We suggest this phased approach for several reasons. Cost-competitive, drop-in biofuel vendors are likely to be limited to a handful of firms in the near term, so Level III LCI data will likely be sufficient for initial best-value tradeoff evaluations. This will likewise enable DLA Energy staff members to become more familiar with the data elements necessary for these sustainability assessments.

This familiarity will enable a progression to phase 1 as DLA Energy and vendors start to discuss the necessary data to calculate the best-value tradeoff metrics and that drive the sustainability assessment against which they are evaluated. As this discussion matures, industry vendors will become more knowledgeable about these selection metrics and maturing voluntary biofuel standards and certification systems and will seek to address this growing voluntary market, which would enable a move to phase 2. As the drop-in biofuel market matures and starts adopting standards compliance or certifications, DLA Energy may be able to then evaluate the procurement impacts of requiring sustainability standards compliance or certification.

DLA Energy's decision to advance to each subsequent phase could be based on industry adoption of such standards and certification systems as well as the cost-benefit of voluntary standards conformance rather than required certifications. This phased approach offers a practical path forward that supports DLA Energy drop-in biofuel procurements in a maturing industry while incrementally incorporating sustainability considerations, improving the product LCI data, and shifting and internalizing the sustainability assessment to the biofuel industry.

SUMMARY RECOMMENDATIONS

In summary, our recommendations are as follows

- ◆ Adopt the proposed sustainability architecture in this report by
 - performing sustainability assessments (likelihood and mitigation only) using Level III LCI data to support best-value tradeoff procurements;
 - performing sustainability assessments utilizing the indicator technical sheets metrics and risk management approach (likelihood, consequence, and mitigation) for due diligence technical reviews of operational demonstrations and facility investment proposals; and
 - using these sustainability assessment processes to identify data gaps (where data are unavailable or highly uncertain), help inform DLA Energy needs, and prioritize its R&D program.

-
- ◆ Integrate the sustainability architecture in DLA Energy business processes by
 - initiating an internal, agency-wide discussion on the sustainability architecture and its integration with DLA business processes;
 - studying the sustainability architecture's compatibility and integration with continuous improvement approaches already used by DLA, federal supply chain, and institutional sustainability programs; and
 - leveraging the sustainability architecture to help DLA achieve *Goal 7, Sustainability Practices Become Norm* in its *Strategic Sustainability Implementation Plan*.
 - ◆ Engage internal stakeholders and external partners by
 - reaching out to DLA, military service, and OSD stakeholders to vet the sustainability framework and build buy-in;
 - engaging these stakeholders to comment on and rank the remaining indicators needed and to be developed in future efforts;
 - identifying data gaps and briefing them annually to the Biomass Research and Development Board;
 - cultivating interagency collaborations and agreements to provide data, analysis, and SME reviews for sustainability assessments; and
 - supporting USDA and EPA data-sharing network efforts to enable bio-fuel sustainability assessments of new and updated pathways.
 - ◆ Align with policy and strategy by
 - discussing affirmative procurement policies and approaches with other DLA business lines;
 - using IAWG to discuss data request strategies, government use sustainability standards and certifications, and FAR implications of best-value tradeoff commodity product purchases;
 - augmenting the DLA Energy sustainability architecture; and
 - considering a phased approach for vendor data package requirements, second-party standards, or third-party sustainability certifications.

CONCLUSION

DLA Energy faces the challenge of purchasing sufficient quantities of advanced biofuel to meet the anticipated demand of the military services, fulfill warfighter requirements, and help attain national security, environmental, and mission sustainability goals—no small task. However, this study offers a foundation, architecture, and components to support DLA Energy in meeting these demands, in a way that informs program, due diligence technical review, and procurement decisions.

We offer DLA Energy staff members a means to gain fuller awareness of the sustainability criteria of these emerging alternative operational fuels as well as standard methods for identifying upstream sustainability benefits, concerns, and uncertainties (not necessarily considered when procuring traditional petroleum-based commodity fuels). The proposed sustainability architecture requires further vetting, incorporation into DLA business processes, and additional development to attain its full value for DLA Energy, DoD, and other agencies. However, the development process has already yielded opportunities and revealed potential partnerships for collaboration moving forward.

In conclusion, DLA Energy now has a relevant, integrative, and systematic capability for identifying, understanding, and managing the tradeoffs associated with the new variety of advanced biofuel products (or other alternative fuels). Although much of our effort involved working through the challenges of the salient environmental criteria, we stayed focused on defining, measuring, and analyzing the relevant characteristics of a sustainable biofuel (an enduring mission enabler). The primary purpose of this sustainability architecture is supporting DLA Energy's technical and procurement processes to ensure the warfighter—today *and* tomorrow—has the operational fuel to accomplish the mission.

Appendix A

Snapshot Examples

The second component of the proposed biofuel sustainability architecture is the pathway snapshot. These documents are intended to quickly summarize the biofuel pathway of interest and their high-level sustainability attributes. The snapshots then provide a detailed description of the feedstock and conversion pathway of interest, a summary table of key sustainability considerations, and a narrative discussion of the noted sustainability benefits, considerations, and concerns.

This study developed a reviewed and revised example pathway snapshot:

- ◆ Soybean Oil HEFA Fuel (revised draft)
- ◆ Waste Oil HEFA Fuel (draft)
- ◆ Camelina Oil HEFA Fuel (draft)

These snapshot examples are provided below.

Pathway Snapshot—Soybean Oil HEFA Fuel

Soybean oil-based hydroprocessed esters and fatty acids (HEFA) is a biomass-based, drop-in fuel blend stock that meets the American Society for Testing and Materials (ASTM) International D7566-11 specification, approved on July 1, 2011.¹ HEFA is commonly referred to as hydroprocessed renewable jet (HRJ). Using a soybean oil feedstock, synthetic biocrude is produced via hydroprocessing and, then refined in a manner similar to petroleum-derived fuels (Figure A-1). Neat HEFA is blended up to 50/50 with conventional kerosene-based jet fuel and is currently certified for use in a growing number of commercial aircraft and US military weapon platforms.

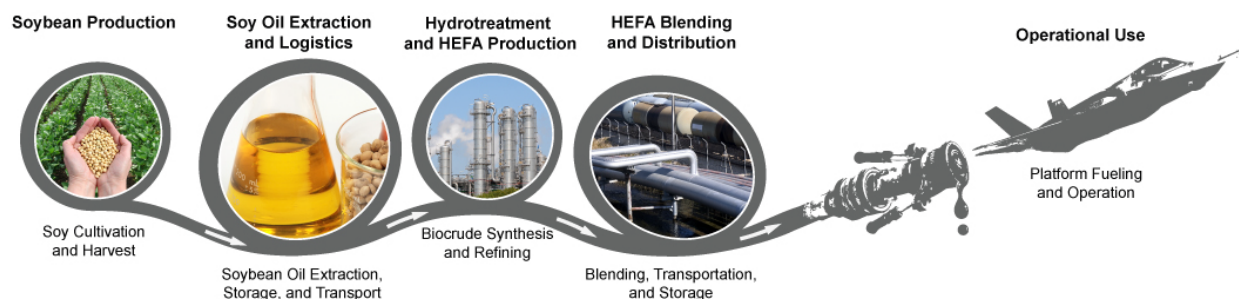


Figure A-1. Soybean Oil HEFA Fuel Pathway

HEFA can be produced using virtually any type of animal or vegetable oil feedstock, but this snapshot focuses solely on the soybean oil feedstock, widely available and used in US biodiesel production. As an agricultural row crop, soybean cultivation requires land, water, fuel, fertilizer, and pesticide inputs with their associated sustainability impacts and benefits. If land is brought into production, land cover, vegetation, and habitat changes may have additive environmental impacts.² As an established food crop, use of soybean oil has socio-economic implications to consider as part of the fuel life cycle. Soybean oil is widely used in fatty acid methyl esters (FAME) biodiesel production and represents bridge feedstock for new biorefineries, supporting the Services' energy security goals. Table A-1 introduces HEFA and summarizes its supply chain sustainability considerations, which are discussed in greater detail in the remainder of this snapshot.

Table A-1. Sustainability Summary for Soybean Oil HEFA Fuel Pathway

	Feedstock Production	Feedstock Preprocessing and Transport	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	+	+	○	+	+
Economic	○	+	■	+	+
Environmental	■	○	○	○	+
Social	○	■	■	○	+
Key + Benefit ○ Consideration ■ Concern					

¹ Enright, C., 2011, Aviation Fuel Standard Takes Flight D7566 Revision Adds Bioderived Components, ASTM Standardization News, www.astm.org/SNEWS/SO_2011/enright_so11.html.

² EPA, *Biofuels and the Environment: First Triennial Report to Congress*, EPA/600/R-10/183F, December 2011.

PATHWAY DETAILED DESCRIPTION

Soybean oil-based HEFA's life cycle and its five discrete stages are presented in Figure A-2. Each of these respective stages is described in the following sections to provide further detail explaining this new drop-in biofuel pathway.

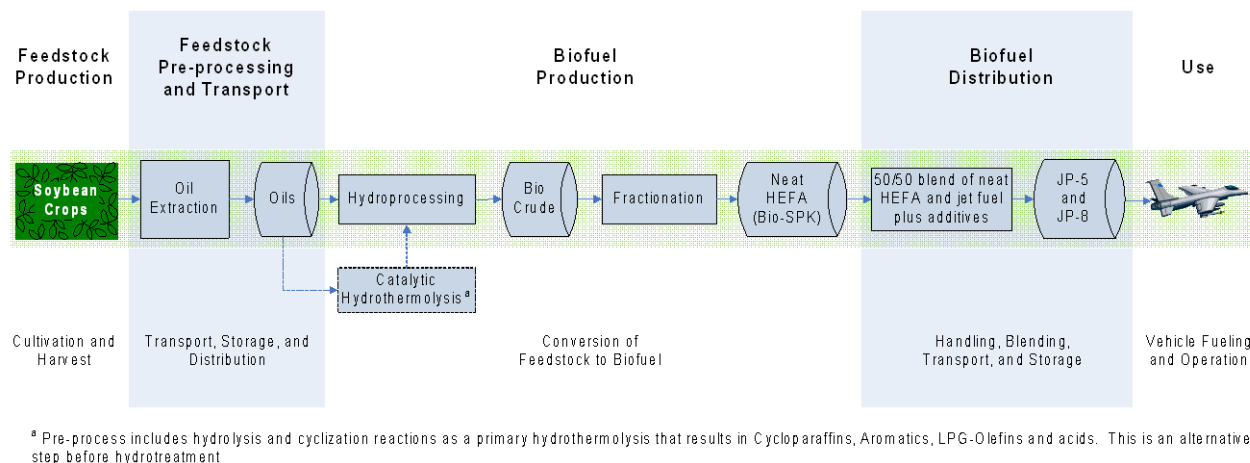


Figure A-2. Soybean Oil-Derived HEFA Production Life cycle Pathway

Feedstock Production

Soybeans cultivation and production is the largest difference between this and other HEFA pathways. Soybean farming and cultivation practices are typical for most row crops. Common agricultural activities performed include:

- ◆ Land acquisition, conversion, and maintenance
- ◆ Installation and use of irrigation and/or drainage systems
- ◆ Tillage, if applicable
- ◆ Planting
- ◆ Application of fertilizers, herbicides, and pesticides
- ◆ Crop harvest

Transport, Storage, and Preprocessing

After harvest, soybeans are transported and stored for oil extraction. Stage 2 of a fuel life cycle is often focused these preprocessing transportation steps. Generally, soybeans are cracked, heated, and treated with a solvent to separate the oil from the meal co-product. Following extraction, the soybean oil is transported to a bio-refinery via rail or tanker truck.

Biofuel Production

At the biorefinery, the soybean oil and hydrogen gas are introduced into a hydro-processing reactor to deoxygenate the triglycerides in the presence of a catalyst and convert them into fully saturated hydrocarbons, or synthetic paraffins. They are then selectively hydrogenated and cracked to produce neat HEFA, sometimes referred to as Bio-SPK (Bio-derived Synthetic Paraffinic Kerosene). This process can be integrated into existing fossil fuel refining facilities and operated at costs approaching that of conventional petroleum refining. The technology can also be added on to first generation biodiesel production facilities, as an added production line at existing petroleum refineries, or built as stand-alone biorefineries.³

Biofuel Distribution and Storage

Following production, neat HEFA is blended up to 50 percent with conventional kerosene-based jet fuel. Blends of more than 50 percent HEFA are not currently certified for use. Additives, such as lubricants, antistatic agents, icing inhibitors, corrosion inhibitors, are added to maintain the desired properties as demanded by the delivered fuel specification, such as Jet A, A-1, jet propulsion (JP)-5, or JP-8.

Neat HEFA and blended fuels are largely transported by truck, barge, or rail, but this may be expanded to pipelines as the scale of production grows. These products are then stored in high-volume, bulk fuel aboveground storage tanks (ASTs), smaller ASTs, and underground storage tanks, and mobile storage conveyances (barges, rail cars, and tanker trucks) prior to their use in vehicles, tactical systems, or weapons platforms.

Biofuel Use

Once blended, HEFA fuels are drop-in substitutes for conventional operational fuels, such as JP-5 and JP-8. The military Services have been qualifying these fuels in tactical systems and certifying weapons platforms so they may be used. JP-8 is primarily used by the Air Force and is very similar to the commercial fuels Jet A and Jet A-1, aside from the use of additional additives.⁴ JP-8 serves as the primary battlefield fuel for the US military so it is also used in tactical ground vehicles, heaters, and electrical generators.⁵ JP-5 is used primarily by the Navy and requires higher flashpoint characteristics to provide an added measure safety aboard ships.

³ Renewable Jet Fuels, renewablejetfuels.org/what-we-do/biofuels-101.




⁴ Chevron Corporation, *Aviation Fuels Technical Review*, FTR-3, 2006, www.cgabusinessdesk.com/document/aviation_tech_review.pdf.

⁵ In April 2004, Department of Defense Directive (DoDD) 4140.25 directed the Services to standardize fuel usage, thereby minimizing the types of fuels required in Joint operations. DoDD 4140.25 designates JP-8 as the primary fuel for air and ground forces in all theaters of operation. Fuel type JP-8 is designated as the single fuel policy fuel (Army Regulation 70-12, July 19, 2012).

KEY PATHWAY SUSTAINABILITY CONSIDERATIONS

This section provides sustainability pillars and criteria level evaluation of the soybean oil-based HEFA life cycle. Table A-2 is a summary of this pathway's positive attributes, considerations, and concerns. It provides a quick visual reference of the life-cycle impacts by criteria and stage. The following section also provides qualitative details on each of these supply chain sustainability considerations.

Table A-2. Sustainability Considerations of Soybean Oil-based HEFA Fuel Pathway

Pillars	Criteria	Life-cycle Stage				
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
		Feedstock Production	Feedstock Processing & Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	Suitability	N/A	N/A	+	+	+
	Energy Security	+	+	+	+	+
	Availability	+	+	○	+	+
Economic	Economic Viability	+	+	■	+	+
	Cost and Price	○	+	○	+	+
Environmental	Water	■	○	○	○	N/A
	Air	■	■	○	○	+
	Land Use	■	○	○	○	N/A
	Soil	■	N/A	N/A	N/A	N/A
	Productivity	○	○	○	N/A	N/A
	Waste	○	○	○	N/A	N/A
	Biological Resources	■	○	○	○	N/A
Social	Food Security	■	■	N/A	N/A	N/A
	Quality of Life	+	+	+	N/A	N/A
	Safety and Health	○	■	■	○	+
	Participation	N/A	N/A	N/A	N/A	N/A
Key  Benefit  Consideration  Concern						

BENEFITS, CONSIDERATIONS, AND CONCERNS

For purposes of this snapshot, the sustainability impacts discussed are within the context of the continental United States. Internationally, increases in US biofuel production and consumption volumes may have consequential or indirect impacts within different countries as trade patterns and prices adjust in response to global supply and demand. This could result in impacts, such as land use change and affect air quality, water quality, and biodiversity, but the location and magnitude of indirect impacts are not considered as part of this summary analysis.⁶

As with many biofuels, the supply chain sustainability considerations are sometimes the most acute and uncertain in the upstream life-cycle stages, particularly the feedstock production stage. Many of the subsequent life-cycle stage activities, processes, and products are well regulated, subject to limitations and contractual requirements, and just appear to perform better than conventional fuel production technologies.⁷ Likewise, the final biofuel-use stage is where many biofuels' benefits become evident and has been driving the interest in these emerging fuel supply chains, despite the upstream supply chain challenges.

Key operational, economic, environmental, and social sustainability considerations associated with the soybean oil HEFA pathway and are discussed below.

Operational

Suitability—The soybean oil-based HEFA pathway is a suitable alternative to conventional petroleum fuels. ASTM approved HEFA pathways can produce on-spec, drop-in fuels that are already certified in numerous weapon platforms and commercial aircraft. Increased fuel payload may be an additional benefit.

Energy Security—The US is the leading global producer of soybeans.⁸ They are an established commodity crop with an existing oil extraction industry. It is already the most widely used feedstock oil in US FAME biodiesel production. Hydrotreatment technology is over 50-years old and was adapted to this purpose under a Defense Advanced Research Projects Agency grant.⁹ HEFA biorefineries are starting to be sited in the continental US and are a domestic supply chain for these advanced biofuels. Once availability concerns are addressed, this pathway appears beneficial for helping to realize the Services' energy security goals.

Availability—Soybeans and soybean oil are well established and traded agricultural commodities. However, commercial scale, HEFA biorefinery facility capacity is a limiting factor in the near-term. Green diesel and HEFA production lines are being financed, sited, and constructed but are progressing at a slow pace.

⁶ See footnote 2, this appendix.

⁷ Ibid.

⁸ United Nations, Food and Agriculture Organization, FAOSTAT Database, 2010, fao-stat3.fao.org/home/index.html#VISUALIZE_TOP_20.

⁹ UOP, Biofuels, Green Jet Fuel, www.uop.com/processing-solutions/biofuels/green-jet-fuel/#green-jet-fuel-process.

Limited commercial scale processing infrastructure raises a concern about the availability of soybean-based HEFA within the timeframe of current military Service alternative fuel goals and demand.

Economic

Economic Viability—At a commercial scale, HEFA fuels appear to be on a trajectory to become economically viable in the mid-term. Soybean oil production is well established and can potentially scale to meet expanded demand more so than other waste or emerging oil feedstock alternatives. Currently, it is a cheaper virgin feedstock than other oil seeds. The pre-processing, storage, and distribution infrastructure for soybeans is already in place, with more capacity being added.¹⁰ In 2009, USDA reported that 75.7 million acres of soybeans were planted, yielding 2,967 million bushels.¹¹ Annual crop yields have increased during the last 10 years, from 38.1 bushels per acre in 2000 to a projected 44 in 2010.¹² USDA projects that technology advances will further increase yields to 46.5 bushels per acre by 2020.¹³ That said, the limited availability of hydrotreatment infrastructure and biorefineries at a commercial scale represents a concern in the near-term. However, petrochemical industry experience with this established technology should not represent a barrier with adequate capital investment and should reduce this to a criterion to a consideration over the next decade. Furthermore, existing transportation, blending, and fueling infrastructure could be utilized, particularly when co-located with existing refineries. As HEFA is ASTM approved, it is a drop-in fuel blend stock that can be used in commercial aircraft and increasingly in military platforms as they are certified.

Cost/Price—Commercial scale, soybean oil-based HEFA fuel should be able to be produced at a cost competitive with conventional Jet A in the mid-term. However, soybean oil-based HEFA may be less cost effective than other non-oil seed feedstocks, such as waste oil, particularly because of existing market demand as a food oil and feedstock for FAME biodiesel production purposes. But, to do so without government subsidies, petroleum crude prices would need to remain in the range of \$80 to \$110 per barrel.¹⁴ More recent projections suggest that this inflection point would likely be in the mid-range of this estimate, assuming capital expenditure financing and off-take agreement barriers are addressed. A further study suggests that profitable HEFA production could only occur at higher spot market prices of greater than \$4.50 per gallon.¹⁵

¹⁰ National Sustainable Agriculture Information Service, *Biodiesel: The Sustainability Dimensions*, attra.ncat.org/attra-pub/PDF/biodiesel_sustainable.pdf.

¹¹ USDA, *Agricultural Projections to 2019*, 2010.

¹² USDA, National Statistics for Soybeans, quickstats.nass.usda.gov/.

¹³ See footnote 11, this appendix.

¹⁴ RAND, *Near-Term Feasibility of Alternative Jet Fuels*, 2009.

¹⁵ Alok Bhargava, Massachusetts Institute of Technology, *Drop-in Replacement Biofuels: Meeting the Challenge*, 2010.

Feedstock is the dominant component of the finished biofuel cost.¹⁶ As soybean oil is a commodity, significant increases in demand as food, FAME, and HEFA feedstock, or price spikes caused by other factors could increase this feedstock's price and negatively impact production cost. In analysis completed prior to the passage of the EISA, USDA estimated that 12.5 percent of the 2017 U.S. soybean crop would be used to produce approximately 39,000 barrels of biodiesel per day. The USDA predicts that meeting the requirements of the EISA will cause soybean production and prices to increase and exports to decrease.¹⁷ However, given HEFA's feedstock flexibility, such costs could be mitigated by shifting oils types and further hedged by diversifying oil types and suppliers. In addition to feedstock cost considerations, HEFA's marginal production costs in stage 3 are likely to be higher than FAME biodiesel production, which makes it a consideration.

Environmental

Water—The soybean oil-based HEFA pathway's implications for water quality are concerns, largely driven by fertilizer and other chemical inputs needed for feedstock production. Overuse, run-off, and export of such chemicals to water bodies can contribute to eutrophication, coastal hypoxia, and other water quality impacts. Good nutrient management and other second-generation feedstocks may offer opportunities to manage and mitigate the risk of these impacts.¹⁸

Most soybean production does not currently require irrigation, but water use could increase in the future if production expands into drier areas or if irrigation is used to increase yields. On a per unit volume basis, the water use for feedstock irrigation can be 100 to 1,000 times higher than the biofuel conversion process itself. Adverse water quantity impacts would most likely arise in surface watersheds already experiencing these availability stresses.¹⁹

Air—Cultivating, tilling, and harvesting of soybeans not only generates airborne particulate matter (dust) but also requires the combustion fuel, both of which result in air pollutant emissions that adversely affect air quality. The EPA suggests that the production of row crops, such as soybeans, can adversely affect air quality more than non-row crops.²⁰ In addition, increased production of fertilizers and pesticides used in soybean cultivation and their application to agricultural fields can generate further air pollution. Expanded soybean oil extraction plant operations may also increase fugitive emissions of the solvent hexane, a volatile organic chemical that has been classified as a hazardous air pollutant.²¹

Land Use and Productivity—Of the other potential concerns raised by increased soybean production, most are a result of or related to land use conversion. Expanded conversion of land currently enrolled in the Conservation Reserve

¹⁶ Ibid.

¹⁷ See footnote 14, this appendix.

¹⁸ See footnote 2, this appendix.

¹⁹ Ibid.

²⁰ Ibid.

²¹ Ibid.

Program (CRP) to soybean cultivation would likely result in or exacerbate many of the aforementioned environmental impacts.²² Conversely, increased productivity, within the limits of existing soil fertility, can effectively reduce the land area needed to generate the same amount of soybeans, oil, and, ultimately, HEFA fuel.

Soil—Soybean production (or over production) can make soil quality a concern, particularly where intensive cultivation impacts erosion rates, organic matter, and nutrient availability. Perennial crops are often less of a concern for soil quality than annual row crops, like soybeans. However, soybean cultivation impacts are largely determined by which land use changes occur and whether proper soil health and conservation practices are implemented.²³

Waste—Production-related solid and hazardous wastes are a consideration. Expanded soybean and oil production may generate more soybean meal and process wastes than the secondary markets can absorb. Furthermore, input and processing chemicals used for cultivation, oil extraction, and HEFA production will generate wastes that need to be minimized, reused, and properly disposed of to avoid becoming a compliance burden, legal liability, or negative environmental concern.

Biological Resources—Feedstock cultivation is a potential concern for biodiversity impacts in circumstances of habitat conversion, especially on CRP lands. Conversion of pasture, CRP lands, or small, unregulated wetlands could decrease habitat availability and impact biodiversity. Conversely, moderate thinning and application of best management or conservation practices can proactively augment habitat that can result in greater species diversity and abundance. Likewise, cultivation-related chemical exposure; erosion rate increases, nutrient releases, or excessive water withdrawals, resulting in decreased stream flow, could all have negative environmental impacts. Weed risk assessments, however, suggest that conventional soybeans pose minimal invasiveness risk.²⁴

Social

Food Security—Processed soybeans are the largest globally source of animal protein feed and the second largest source of vegetable oil. The US is the world's leading soybean producer and exporter. Soybeans represent “about 90 percent of US oilseed production.”²⁵ Increased biofuel production demand for soybean oil could divert increasing proportions of this commodity from human consumption, but only the oil. Soybeans contain approximately 21 percent oil on a dry weight basis.²⁶ Expanded demand for soybean oil could potentially expand the co-production of soymeal and would make greater quantities of these protein sources available for animal and human consumption. Likewise, if soybean oil demand

²² Ibid.

²³ Ibid.

²⁴ Ibid.

²⁵ USDA, Economic Research Service, www.ers.usda.gov/topics/crops/soybeans-oil-crops.aspx.

²⁶ Bailey's Industrial Oil and Fat Products, Sixth Edition, 2005, uqu.edu.sa/files2/tiny_mce/plugins/filemanager/files/4281709/84607_28.pdf.

significantly increases, soybean meal consumers could see lower prices because of excess production. Soybean crops have historically outpaced demand so the food security concerns may in actuality only be a consideration.²⁷

Quality of Life—Expanded production of soybeans, soybean oil, and biofuel production is a benefit of this pathway. Increasing land under cultivation, new oil extraction plants, and new biorefineries would provide agricultural and chemical industry employment opportunities. Soybean cultivation would also not require significant retraining or education of existing workers as it is a well known commodity crop and production system.

Safety and Health—Increased soybean production would not seem to pose a direct safety and health concern any more than other annual row crops. However, significantly expanded oil extraction in both scope and location could increase occupational and community exposure to hexane air emissions. Likewise, new biorefinery employees and surrounding communities could face chemical exposure safety and health hazards similar to existing petrochemical refineries. However, greater biofuel use and combustion may conversely reduce health concerns and burden by reduced air emissions and improved air quality.

²⁷ United Soybean Board, *Food and Fuel*, www.soyconnection.com/soybean_oil/pdf/foodvsfuel_soy_biofuels.pdf.

Pathway Snapshot—Waste Oil HEFA Fuel

Biogenic waste oil-based hydroprocessed esters and fatty acids (HEFA) is a biomass-based, drop-in fuel blend stock that meets the American Society for Testing and Materials (ASTM) International D7566-11 specification, approved on July 1, 2011.²⁸ HEFA is commonly referred to as hydroprocessed renewable jet fuel. Using a biogenic waste oil feedstock (waste animal and vegetable fats, oils, and greases), synthetic biocrude can be produced via hydroprocessing and, then refined in a manner similar to petroleum-derived fuels (Figure 1). Neat HEFA can be blended up to 50/50 with conventional kerosene-based jet fuel and is certified for use in a growing number of commercial aircraft and US military weapon platforms.

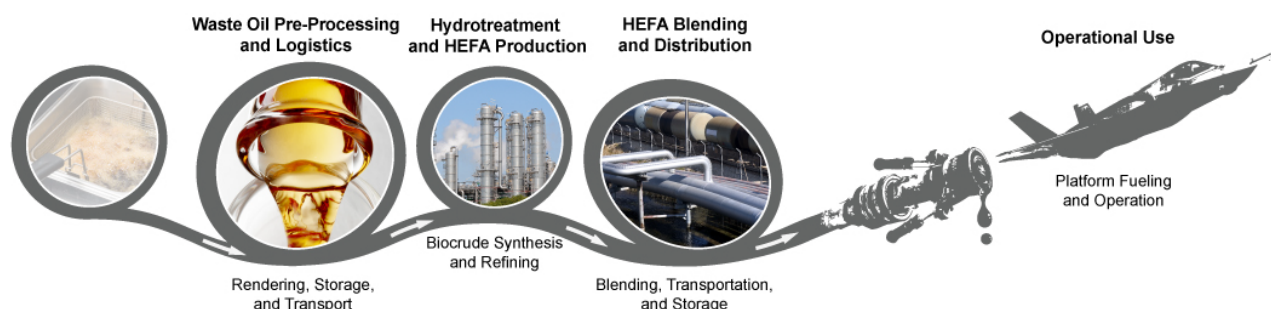


Figure 2. Waste Oil HEFA Fuel Pathway

HEFA blend stock can be produced using virtually any type of animal or vegetable oil feedstock, but this snapshot focuses solely on biogenic waste oil feedstock, which is widely available and already used for US biodiesel production. As a waste product, biogenic waste oils (from cooking, food and animal processing activities) sustainability considerations in stage 1 are limited as current life-cycle inventory boundaries generally exclude or discount impacts during feedstock production. Waste oil, often known as yellow grease, is used in fatty acid methyl esters (FAME) biodiesel production. It is low cost feedstock that can support new drop-in HEFA production and the achievement of the military services' energy security goals. Table 1 introduces waste oil HEFA and summarizes its supply chain sustainability considerations, which are discussed in greater detail throughout the remainder of this snapshot.

Table 1. Sustainability Summary for Waste Oil HEFA Fuel Pathway

	Feedstock Production	Feedstock Preprocessing and Transport	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	⊙	⊙	⊙	+	+
Economic	+	+	■	+	+
Environmental	+	⊙	⊙	⊙	+
Social	⊙	⊙	■	⊙	+
Key + Benefit ⊙ Consideration ■ Concern					

²⁸ See footnote 1, this appendix.

PATHWAY DETAILED DESCRIPTION

Waste oil-based HEFA's life-cycle and its five discrete stages are presented in Figure 2. Each of these respective stages is described in the following sections to provide further detail concerning this advanced, drop-in biofuel pathway.

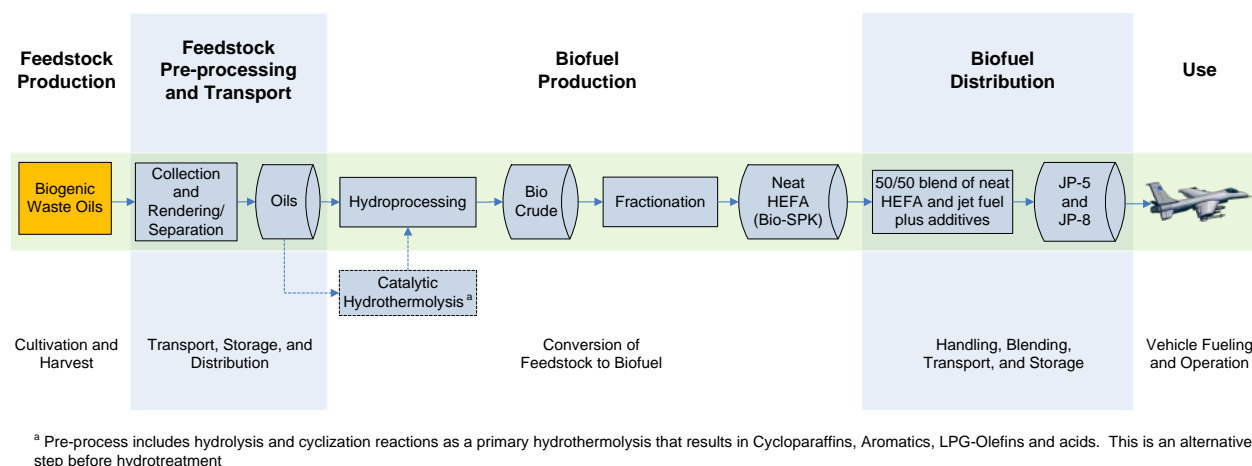


Figure 2. Waste Oil-Derived HEFA Production Life-cycle Pathway

Feedstock Production

Waste oils, fats, and greases are generated by restaurants and food processors. They also are produced from animal processing wastes at rendering plants. Generally, rendering operations that contract grease removal from restaurants or who process animals, are the primary wholesale sources of waste oils. Recycled cooking oils or greases are usually sold under the commodity name of yellow grease.²⁹ Yellow grease is a commonly used waste feedstock in biofuel production. Brown grease, collected from grease traps, is a lesser valued commodity due to its greater contamination and variability, but which are also gaining interest as a potential feedstock. Inedible tallows are produced from rendering of animal products and are an additional feedstock source within the category of waste fat, oil, and grease. Following rendering, tallow may be further processed to produce oil suitable for conversion into fuel. Additional steps may be required and include screening, centrifuge, settling, heating, filtering, and chemical extraction. As animal processing wastes and yellow or brown grease are waste products, current life-cycle inventory boundaries often exclude their stage 1 attributes. As such, our analysis primarily considers the pathway from stage 2, starting with the collection, rendering, or other preprocessing steps.

²⁹ National Renderers Association (NRA), *Collecting Recycled Cooking Oils or Greases for Biofuels*, 2008.

Collection, Logistics, and Preprocessing

Unprocessed greases are collected from retail locations but may contain over 50 percent impurities, such as water and food particles. As such, it must undergo preprocessing before it is suitable for biocrude synthesis and refinement. At rendering facilities, raw waste oils are unloaded, decanted, and the wastewater removed. The yellow grease is heated and the solid fractions separated out.³⁰

Recycled yellow grease may also require additional processing to remove contaminants, such as sulfur. The recycled waste oil is then transported via rail or tanker truck but may require special handling to reduce degradation, such as maintaining the temperature above 65°C to thwart bacteria growth and enzymatic activity.³¹

Biofuel Production

At biorefinery, the recycled waste oils and hydrogen gas are introduced into a hydroprocessing reactor to deoxygenate the triglycerides in the presence of a catalyst and convert them into fully saturated hydrocarbons, or synthetic paraffins. They are then selectively hydrogenated and cracked to produce neat HEFA. This process can be integrated into existing fossil fuel refining facilities and operated alongside of the conventional petroleum refining process. The technology can also be added on to first generation biodiesel production facilities, as an added production line at existing petroleum refineries, or built as stand-alone biorefineries.³² The higher levels of saturated animal fats and free fatty acids in waste oils may require additional processing to produce finished fuel that meets ASTM specifications.³³

Biofuel Distribution and Storage

Following production, neat HEFA is blended up to 50 percent with conventional kerosene-based jet fuel. Blends of more than 50 percent HEFA are not currently certified for use. Additives, such as lubricants, antistatic agents, icing inhibitors, corrosion inhibitors, are added to maintain the desired properties as demanded by the delivered fuel specification, such as Jet A, A-1, jet propulsion (JP)-5, or JP-8. Neat HEFA and blended fuels are largely transported by truck, barge, or rail, but this may be expanded to pipelines as the scale of production grows. These products are then stored in high-volume, bulk fuel aboveground storage tanks, underground storage tanks and mobile storage conveyances (barges, rail cars, and tanker trucks) prior to their use in tactical systems or weapons platforms.

³⁰ Ibid.

³¹ Airport Cooperative Research Program, *Guidelines for Integrating Alternative Jet Fuel into the Airport Setting*, 2012.

³² See footnote 3, this appendix.

³³ See footnote 24, this appendix.

Biofuel Use

Once blended, HEFA fuels are drop-in substitutes for conventional operational fuels, such as JP-5 and JP-8. The military services have been qualifying these fuels for use in tactical systems and certifying weapons platforms. JP-8 is primarily used by the Air Force and is similar to the commercial fuels Jet A and Jet A-1, aside from the use of additional additives.³⁴ JP-8 serves as the primary battlefield fuel for the US military so it is also used in tactical vehicles, heaters, and electrical generators.³⁵ JP-5 is used primarily by the Navy and requires higher flashpoint characteristics to provide an added safety measure aboard ships.

KEY PATHWAY SUSTAINABILITY CONSIDERATIONS

This section provides sustainability pillars and criteria level evaluation of the waste oil HEFA life cycle. Table 2 is a summary of this pathway's benefits, considerations, and concerns. It provides a quick visual reference of the life-cycle considerations by criteria and stage. The subsequent section provides qualitative details on each of these supply chain sustainability considerations.

Table 2. Sustainability Considerations of Waste Oil HEFA Fuel Pathway

Pillars	Criteria	Life-cycle Stage				
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
		Feedstock Production	Feedstock Processing & Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	Suitability	N/A	N/A	+	+	+
	Energy Security	+	+	+	+	+
	Availability	⊙	⊙	⊙	+	+
Economic	Economic Viability	+	+	■	+	+
	Cost and Price	+	+	⊙	+	+
Environmental	Water	+	+	⊙	⊙	N/A
	Air	+	+	⊙	⊙	+
	Land Use	+	⊙	⊙	⊙	N/A
	Soil	+	N/A	N/A	N/A	N/A
	Productivity	+	⊙	⊙	N/A	N/A
	Waste	+	⊙	⊙	N/A	N/A
	Biological	+	⊙	⊙	⊙	N/A

³⁴ See footnote 4, this appendix.

³⁵ See footnote 5, this appendix.

Pillars	Criteria	Life-cycle Stage				
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
		Feedstock Production	Feedstock Processing & Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
	Resources					
Social	Food Security			N/A	N/A	N/A
	Quality of Life				N/A	N/A
	Safety and Health					
	Participation	N/A	N/A	N/A	N/A	N/A
Key Benefit Consideration Concern						

BENEFITS, CONSIDERATIONS, AND CONCERNS

For purposes of this snapshot, the sustainability impacts discussed are within the context of the continental United States. Internationally, increases in US biofuel production and consumption volumes may have consequential or indirect impacts within different countries as trade patterns and prices adjust in response to global supply and demand. This could result in impacts, such as land use change and effects in air quality, water quality, biodiversity, etc.³⁶ But, given the immaturity of consequential analysis approaches, these indirect impacts are not considered.

As with many biofuels, the supply chain sustainability considerations are sometimes the most acute and uncertain in the upstream life-cycle stages, particularly the feedstock production stage. Many of the subsequent life-cycle stage activities, processes, and products are well regulated, subject to limitations and contractual requirements, and just appear to perform better than conventional fuel production technologies.³⁷ Likewise, the final biofuel-use stage is where many biofuels' benefits become evident and has been driving the interest in these emerging fuel supply chains, despite the upstream supply chain challenges.

Key operational, economic, environmental, and social sustainability considerations associated with the waste oil HEFA pathway are discussed below.

³⁶ See footnote 2, this appendix.

³⁷ Ibid.

Operational

Suitability—The waste oil HEFA pathway is a suitable alternative to conventional petroleum fuels and was utilized in the recent Green Strike Group demonstration at the 2012 Rim of the Pacific Exercise. The ASTM-approved HEFA pathway can provide on-spec, drop-in fuels that are already certified in numerous weapon platforms and commercial aircraft. Increased fuel payload may be an additional benefit.

Energy Security—Waste oil is a proven feedstock for the production of biodiesel and now for green diesel and HEFA pathways. Preprocessing and logistical networks are established and expanding. Biorefineries are already being built in the continental United States and domestic supply chains for these advanced biofuels are emerging. Although there is a steady supply of waste oil, it is limited in quantity. Waste oil is a less costly alternative feedstock compared with virgin food oil (soybean) or energy crop oils (camelina), but its finite supply will limit its contribution to meeting DoD and military service energy security goals.

Availability—Locally, waste fats, oils, and greases are more readily available and abundant in large metropolitan areas, with greater numbers of restaurants, and in regions with significant meat processing operations. At the national level, the supply of waste oil is consistent but still finite. Expanding beyond yellow grease to other forms of waste oil, such as tallow, could provide additional feedstock capacity but will compete with other industries, such as soap production. In 2011, the US production of inedible tallow and grease was nearly 2.7 million metric tons out of the 4.3 million metric tons of total animal fats and greases production.³⁸ Projections indicate that availability of animal fats and greases will increase, with total animal fats and greases production projected to surge by 18 percent from 4.3 million metric tons to 5.1 million metric tons by 2021.³⁹

Commercial scale HEFA biorefinery facility capacity is a limiting factor in the near-term. Green diesel and HEFA production lines are being financed, sited, and constructed but are progressing at a slow pace. Finite feedstock quantities and limited commercial scale processing infrastructure is a consideration, particularly within the time frame of current military service alternative fuel goals.

Economic

Economic Viability—At a commercial scale, HEFA fuels appear to be on a trajectory to become economically viable but only in the mid-term. Waste oil is one of the least expensive feedstocks for HEFA and already has established collection and preprocessing infrastructure. Petrochemical industry experience with hydrotreating technology is extensive and should not represent a barrier with adequate capital investment and should reduce this criterion to a consideration over the next decade. Furthermore, existing transportation, blending, and fueling infrastructure could be utilized and may be beneficial, particularly when co-located

³⁸ Swisher, NRA, *Market Report*, Renderer Magazine, 2012.

³⁹ Ibid.

with existing refineries. As HEFA is ASTM approved, it is a drop-in fuel blend stock that can be used in commercial aircraft and increasingly in military platforms as they are certified.

Cost/Price—Commercial scale, waste oil-based HEFA fuel should be able to be produced at a cost competitive with conventional Jet A in the mid-term. Feedstock is the dominant component of the finished biofuel cost.⁴⁰ Waste oil-based HEFA is more cost effective than virgin oil seed feedstocks, such as soybean, particularly because of the existing market demand as a food oil and feedstock for FAME biodiesel production purposes. However, the average price for rendered fats and greases was at an all-time record high in 2011. Agricultural Marketing Service reports show that the average inedible tallow price was \$1,097 per metric ton, up over 34 percent from 2010. Yellow grease averaged \$957, up 38 percent from the previous year.⁴¹ If prices continue to escalate, the gap between waste oil and virgin food oils such as soybeans may narrow. In addition to feedstock cost considerations, HEFA's marginal production costs in stage 3 are likely to be higher than FAME biodiesel production, which makes it a consideration.

Environmental

Water—The waste oil-based HEFA pathway's implications for water quality are benefits. Although there are considerations for pre-processing and rendering, these activities are largely regulated via discharge permits. Additionally, the incentive to remove greater quantities of waste oils from wastewater discharges and reduce illicit disposal of waste oils may benefit water quality. However, new biorefineries will likely generate contaminated process water and require treatment and discharge permits. However, given this is not unique to this pathway and is highly regulated, this and blending operations are rated as a consideration.

Air—Although there are considerations for pre-processing, rendering, biofuel production, and distribution, these activities are largely regulated. Greenhouse gas and other emissions from waste oil HEFA would be anticipated to be lower than those of conventional fuels or virgin oil feedstocks, which are considered a benefit.

Land Use, Productivity, and Soil—Increased utilization of recycled waste oils would help reduce consumption of virgin agricultural commodities as well as petroleum resources indirectly. Use of this waste material would have a negligible impact on land use in stages 2, 3, and 4 so they are only considerations. Inconsistent waste oils could decrease productivity if not monitored so this is likewise a consideration in stages 2 and 3. For similar reasons to land use, increased use of recycled waste oils would have a beneficial impact on soil in stage 1. It is not considered to be applicable in remaining life-cycle stages.

⁴⁰ Ibid.

⁴¹ Ibid.

Waste—Indirectly, waste oil used in a biofuel feedstock could be beneficial due to reduced landfill disposal burdens associated with animal processing wastes and waste grease. Pre-processing and biorefinery production-related solid and hazardous wastes will need to be managed under existing regulations but are not significantly different than existing operations so they are a consideration, but not a concern.

Biological Resources—Greater utilization of recycled waste oils could have an indirectly beneficial impact on biological resources. Reduced demand for petroleum and agricultural commodities could mitigate potential impacts from expanded petroleum extraction and from the production of virgin vegetable oil feedstocks. However, new or expanded preprocessing facilities, biorefineries, and distribution infrastructure would require construction and land disturbance. As such, this would be a consideration across stages 2, 3, and 4.

Social

Food Security—Use of inedible fats, oil, and greases would not directly affect food security and is likely beneficial over virgin food oil-derived HEFA pathways. However, yellow grease is used as an ingredient for livestock, poultry, and aquaculture feeds.⁴² Increased demand and associated cost increases could impact food prices and represents a consideration for preprocessing operations standpoint.

Quality of Life—Increased collection and utilization of waste oil in drop-in biofuel production is considered a direct and indirect benefit. From collection and preprocessing to biofuel production, expansion of this pathway will likely generate and sustain a variety of employment opportunities along the entire value chain.

Safety and Health—The waste oil collection and preprocessing operations could represent an increased occupational and community exposure to pests and chemicals and is a consideration. Likewise, new biorefinery employees and surrounding communities could face new chemical exposure, safety, and health hazards similar to existing petrochemical refineries or other biorefinery technologies, which may represent a concern. However, most if not all, drop-in biofuels producers, employees, and surrounding communities will face these same risks, but are likewise subject to robust regulation. While HEFA distribution is an occupational health exposure consideration, final use may reduce health concerns and burdens compared with conventional petroleum products through lower air emissions and improved local air quality.

⁴² Weber, Feedstock Supplies for US Biodiesel Production, 2009.

Pathway Snapshot—Camelina Oil HEFA Fuel

Camelina oil-based hydroprocessed esters and fatty acids (HEFA) is a biomass-based, drop-in fuel blend stock that meets the American Society for Testing and Materials (ASTM) International D7566-11 specification, approved on July 1, 2011.⁴³ *Camelina sativa* (camelina) is an oilseed crop within the flowering plant family Brassicaceae, native to Northern Europe and Central Asia, and starting to be grown in the northwestern United States.⁴⁴ Using a camelina oil feedstock, synthetic biocrude is produced via hydroprocessing and, then refined in a manner similar to petroleum-derived fuels (Figure 1). Neat HEFA is blended up to 50/50 with conventional kerosene-based jet fuel and is currently certified for use in a growing number of commercial aircraft and US military weapon platforms.

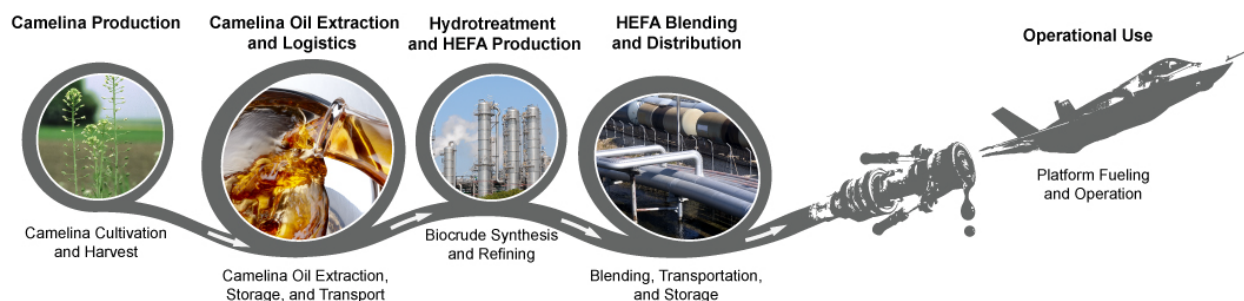


Figure 3. Camelina Oil HEFA Fuel Pathway

HEFA can be produced using virtually any type of animal or vegetable oil feedstock, but this snapshot focuses solely on the camelina oil HEFA pathway. Camelina is an emerging energy crop often cultivated as a rotational cover crop on fallow land. As camelina integrates with wheat and other cropping systems, new land would not necessarily need to be brought into agricultural production. Given its low water and nutrient requirements, it may be environmentally beneficial compared with other oil seed crops. Camelina is not a common food oil crop and is not expected to significantly displace other agricultural commodity crops. Table 1 introduces the camelina HEFA pathway's sustainability considerations, which are discussed in greater detail in the remainder of this snapshot.

Table 1. Sustainability Summary for Camelina Oil HEFA Fuel Pathway

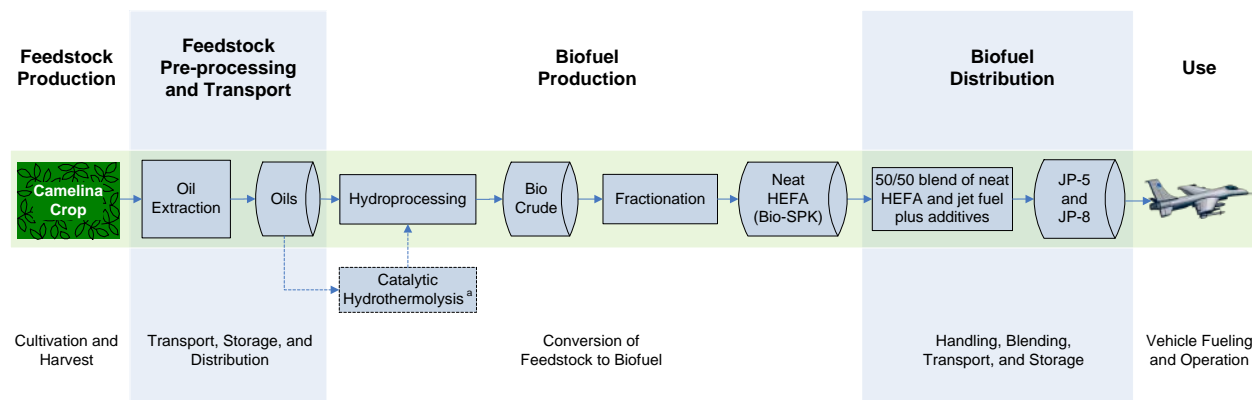
	Feedstock Production	Feedstock Preprocessing and Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	Concern	Consideration	Consideration	Benefit	Benefit
Economic	Concern	Consideration	Concern	Benefit	Benefit
Environmental	Benefit	Consideration	Consideration	Consideration	Benefit
Social	Benefit	Concern	Concern	Consideration	Benefit
Key + Benefit ○ Consideration - Concern					

⁴³ See footnote 1, this appendix.

⁴⁴ EPA, *Regulation of Fuels and Fuel Additives: Identification of Additional Qualifying Renewable Fuel Pathways Under the Renewable Fuel Standard Program*, 77 Federal Regulation (FR) 700, January 5, 2012.

PATHWAY DETAILED DESCRIPTION

Camelina oil-based HEFA's five life-cycle stages are presented in Figure 2. Each of these respective stages is described in further detail in the following sections.



^a Pre-process includes hydrolysis and cyclization reactions as a primary hydrothermolysis that results in Cycloparaffins, Aromatics, LPG-Olefins and acids. This is an alternative step before hydrotreatment

Figure 2. Camelina Oil-Derived HEFA Pathway Production Life-cycle

Feedstock Production

Camelina is an emerging oil seed, rotation cover crop that can be integrated with wheat or other existing commodity cropping systems, particularly within dry land agriculture in the US northwest. The agricultural activities anticipated during feedstock production include:

- ◆ Land acquisition, use, and maintenance
- ◆ Planting
- ◆ Application of fertilizers, herbicides, and pesticides, as necessary
- ◆ Crop harvest.

Camelina's cold tolerance and low moisture requirements allow it to be grown in areas often unsuitable for other major oilseed crops, such as soybeans, sunflower, and canola/rapeseed. It often requires the use of little to no tillage and has a relatively short growing season (less than 100 days). Camelina can be grown either as a spring annual or as winter cover crop in milder climates. As an alternative to a fallow period, it can be used to break the continuous planting cycle of certain grains, reducing the disease, insect, and weed pressures. Market analysis indicates that camelina is likely to be grown in rotation with winter wheat in dry land agriculture.⁴⁵ Once mature, the camellia is then harvested in a manner similar to wheat.⁴⁶

⁴⁵ DoD, *Opportunities for DoD use of Alternative and Renewable Fuels, FY10 NDAA* [National Defense Authorization Act] *Section 334 Congressional Study*, July 2011.

⁴⁶ See footnote 44, this appendix.

Transport, Storage, and Preprocessing

After harvest, camelina seeds are transported and stored for oil extraction. Camelina seeds are then crushed and heated with steam to separate the oil from the meal co-product. Given that camelina seeds are small, transportation and crushing can be more challenging than relatively larger oil seeds. Camelina oil can be thick and gummy at warm temperatures and the residual meal can be prone to combustion so appropriate care must be taken during this stage.⁴⁷ Following extraction, the camelina oil is transported to a biorefinery via rail or tanker truck.

Biofuel Production

At the biorefinery, the camelina oil and hydrogen gas are introduced into a hydroprocessing reactor to deoxygenate the triglycerides in the presence of a catalyst and convert them into fully saturated hydrocarbons, or synthetic paraffins. They are then selectively hydrogenated and cracked to produce neat HEFA, sometimes referred to as Bio-SPK (Bio-derived Synthetic Paraffinic Kerosene). This process can be integrated into existing petrochemical refining facilities and operated at costs approaching that of conventional petroleum refining. The technology can also be added on to first generation biodiesel production facilities, an added production line at existing petroleum refineries, or as a stand-alone biorefinery.⁴⁸

Biofuel Distribution and Storage

Neat HEFA is blended up to 50 percent with conventional kerosene-based jet fuel. Blends of more than 50 percent HEFA are not currently certified for use. Additives, such as lubricants, antistatic agents, icing inhibitors, and corrosion inhibitors, are added to maintain the desired properties as demanded by the delivered fuel specification, such as Jet A, A-1, jet propulsion (JP)-5, or JP-8. The blended fuels are largely transported by truck, barge, or rail, but this may be expanded to pipelines as the scale of production grows. These products are then stored in high-volume, bulk fuel aboveground storage tanks (ASTs), smaller ASTs, underground storage tanks, and mobile storage conveyances (barges, rail cars, and tanker trucks) prior to their use in tactical systems or weapons platforms.

Biofuel Use

Once blended, HEFA fuels are drop-in substitutes for conventional operational fuels, such as JP-5 and JP-8. The military services have been qualifying these fuels for use in tactical systems and certifying weapons platforms. JP-8 is primarily used by the Air Force and is very similar to the commercial fuels Jet A and Jet A-1, aside from the use of additional additives.⁴⁹ JP-8 serves as the primary battlefield fuel for the US military so it is also used in tactical ground

⁴⁷ See footnote 45, this appendix.

⁴⁸ See footnote 3, this appendix.


⁴⁹ See footnote 4, this appendix.

vehicles, heaters, and electrical generators.⁵⁰ JP-5 is used primarily by the Navy and has higher flashpoint characteristics to provide an added safety measure aboard ships.

KEY PATHWAY SUSTAINABILITY CONSIDERATIONS

This section provides sustainability pillars and criteria level evaluation of the camelina oil-based HEFA life cycle. Table 2 is a quick visual summary of this pathway's benefits, considerations, and concerns by criteria and stage. The following section provides qualitative details on each of these considerations.

Table 2. Sustainability Considerations of Camelina Oil HEFA Fuel

Pillars	Criteria	Life-cycle Stage				
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
		Feedstock Production	Feedstock Processing & Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
Operational	Suitability	N/A	N/A	+	+	+
	Energy Security	+	+	+	+	+
	Availability	-	○	○	+	+
Economic	Economic Viability	-	○	-	+	+
	Cost and Price	-	○	○	+	+
Environmental	Water	+	○	○	○	N/A
	Air	○	-	○	○	+
	Land Use	+	○	○	○	N/A
	Soil	+	N/A	N/A	N/A	N/A
	Productivity	+	○	○	N/A	N/A
	Waste	○	○	○	N/A	N/A
	Biological Resources	+	○	○	○	N/A
Social	Food Security	+	+	N/A	N/A	N/A
	Quality of Life	+	+	+	N/A	N/A
	Safety and Health	+	-	-	○	+
	Participation	N/A	N/A	N/A	N/A	N/A
Key  Benefit						

⁵⁰ See footnote 5, this appendix.

Pillars	Criteria	Life-cycle Stage				
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
		Feedstock Production	Feedstock Processing & Logistics	Biofuel Production	Biofuel Distribution	Biofuel Use
<div><div></div> Consideration</div> <div><div></div> Concern</div>						

BENEFITS, CONSIDERATIONS, AND CONCERNS

For purposes of this snapshot, the sustainability impacts discussed are within the context of the continental United States. Internationally, increases in US biofuel production and consumption volumes may have consequential or indirect impacts within different countries as trade patterns and prices adjust in response to global supply and demand. This could result in impacts, such as land use change and effects in air quality, water quality, biodiversity, and food security, but these indirect impacts are not considered as part of this snapshot analysis.⁵¹

As with many biofuels, the supply chain sustainability considerations are sometimes the most acute and uncertain in the upstream life-cycle stages, particularly the feedstock production stage. Many of the subsequent life-cycle stage activities, processes, and products are well regulated, subject to limitations and contractual requirements, and just appear to perform better than conventional fuel production technologies.⁵² Likewise, the final biofuel-use stage is where many biofuels' benefits become evident and has been driving the interest in these emerging fuel supply chains, despite the upstream supply chain challenges.

Key operational, economic, environmental, and social sustainability considerations associated with the soybean oil HEFA pathway are discussed below.

Operational

Suitability—The camelina oil HEFA pathway is a suitable alternative to conventional petroleum fuels. ASTM-approved HEFA blend stock can produce on-spec, drop-in fuels that are already certified in numerous weapon platforms and commercial aircraft. Increased fuel payload may be an additional benefit.

Energy Security—Camelina is an emerging feedstock for producing HEFA fuel blend stock. Camelina feedstock production is anticipated to grow moving forward; but only 68–98 million gallons of annual HEFA production is anticipated by 2020.⁵³ It offers some diversification of feedstock and resultant enhancement of energy security, but its limited availability will temper the significance of the real energy security benefits in the near-term. From a net energy balance standpoint, camelina

⁵¹ See footnote 2, this appendix.

⁵² Ibid.

⁵³ See footnote 45, this appendix.

grown on disperse fallow land could potentially require more energy to produce than other oilseed crops.⁵⁴ Camelina seeds do, however, benefit from high oil content so the energy needed to transport camelina seeds in stage 2 may be lower than feedstock oils produced from other oilseed crops, such as soy beans.

Availability—Camelina is not currently cultivated widely and is a concern for feedstock production. The US Department of Agriculture does not currently consider camelina as an agricultural commodity crop and, as such, the ability to effectively market and obtain crop insurance for existing production is limited. Oil seed extraction infrastructure exists but may need to be expanded, which is a consideration. Commercial scale, HEFA biorefinery facility capacity is also a limiting factor in the near-term. Green diesel and HEFA production facilities are being financed, sited, and constructed but are progressing at a slow pace. Limited commercial scale processing infrastructure raises a concern about the availability of camelina-based HEFA within the time frame of current military service alternative fuel goals.

Economic

Economic Viability—Camelina seed and oil production is emergent and unclear. It isn't yet designated or traded as an agricultural commodity so it isn't eligible for crop insurance. Producers don't have good marketing mechanisms so it is a concern. The pre-processing, storage, and distribution infrastructure for camelina is similar to other crops so minimal investment in equipment will be required, except for future scale-up capacity issues. However, as camelina seeds are small, transportation and crushing can be more difficult than relatively larger oil seeds. Camelina oil can be thick and gummy at warm temperatures and the residual meal, though a valuable co-product, can be prone to combustion.⁵⁵ Both factors could contribute to storage and handling challenges before and during crushing so it is a consideration.⁵⁶ That said, the limited availability of hydrotreatment infrastructure and biorefineries at a commercial scale represents a concern in the near-term. However, petrochemical industry experience with this established technology should not represent a barrier with adequate capital investment and should reduce this to a consideration over the next decade. Furthermore, existing transportation, blending, and fueling infrastructure could be utilized, particularly when co-located with existing refineries. As HEFA is ASTM approved, it is a drop-in fuel blend stock that can be transported using conventional distribution infrastructure and used in certified commercial aircraft and military platforms, which are all considered benefits.

Cost/Price—Commercial scale HEFA fuel projection appear to be on a trajectory to become economically viable in the mid-term, given Energy Information Administration petroleum fuel projections.⁵⁷ But, the price competitiveness of

⁵⁴ See footnote 44, this appendix.

⁵⁵ See footnote 45, this appendix.

⁵⁶ Ibid.

⁵⁷ Ibid.

camelina seeds and oil is unclear as it is not yet a traded commodity so it is a concern. Once cultivated, camelina seeds do have a higher percentage of oil content per pound than traditional oilseed crops, such as soybeans. Soybeans contain ~18 percent oil, whereas camelina seeds contain ~36 percent oil, which represent up to a two-fold increase in oil yield per pound of feedstock.⁵⁸ Furthermore, camelina meal may have a beneficial omega-3 characteristic for animal feed so this co-product may contribute to the value chain. However, camelina seed size, its extract oil's consistency (thick and gummy), and the residual meal combustibility could contribute to higher storage and handling costs before and during crushing.⁵⁹ Given these benefits, concerns, and uncertainties, the stage 2 cost implications are a consideration. Feedstock is the dominant component of the finished biofuel cost, but, HEFA's marginal production costs in stage 3 are likely to be higher than FAME biodiesel production, which makes it a concern in the near-term. However, as a drop-in fuel, distribution and use should be similar to conventional petroleum bulk fuels, which is a benefit.

Environmental

Water—Camelina's shallow rooting and drought resistance may reduce water demand and is a benefit. Additionally, no or reduced tillage will minimize runoff and sedimentation during rain events. Its limited need of fertilizers, herbicides, and pesticides inputs have the potential to reduce deterioration of receiving streams and water bodies over other oil seed crops. Although there are water quality considerations for oil extraction, these activities are largely regulated via discharge permits. New biorefineries will likely generate contaminated process water, require treatment and discharge permits. However, given this is not unique to this pathway and highly regulated, these and blending operations are only considerations.

Air—Due to high oil yields, no-till cultivation, and integration with existing cropping systems, air quality impacts from camelina production are expected to be same or lower than for other oil seed crops, such as soybeans. Fertilizer, herbicide, and pesticide use applications to agricultural fields can generate air pollution, but again, initial experience with camelina indicates minimal need for such inputs. However, expanded camelina oil extraction preprocessing operations may increase fugitive emissions of the solvent hexane, which is a volatile organic chemical that has been classified as a hazardous air pollutant. Ultimately, compared with conventional petroleum products, the camelina oil HEFA pathway appears to be more beneficial in terms of greenhouse gas and air emissions, particularly in stage 5.

Land Use and Productivity—In its qualification review for the Renewable Fuel Standard, EPA reviewed camelina and found that the agricultural inputs are similar to those for growing soy beans and direct land use impact is expected to be negligible due to planting on land that would be otherwise fallow.⁶⁰ To date,

⁵⁸ See footnote 44, this appendix.

⁵⁹ See footnote 45, this appendix.

⁶⁰ See footnote 44, this appendix.

limited production and use of camelina indicates no expected impacts on other crops and no indirect land use impacts.⁶¹ However, expanded cultivation of camelina on land currently enrolled in the Conservation Reserve Program (CRP) would likely result in or exacerbate many of the aforementioned environmental impacts.⁶² Conversely, increased productivity, within the limits of existing soil fertility, can effectively reduce the land area needed to generate the same amount of camelina, oil, and, ultimately, HEFA fuel.

Soil—One of camelina’s primary benefits is its limited nutrient requirements, which is what enables its use as a cover crop on fallow land. Further, no till cultivation methods and its use as a cover crop is likely to reduce erosion and soil degradation. As such, camelina cultivation may benefit soil quantity and possibly quality, particularly when compared with other oil seed crops that require more intensive cultivation practices.

Waste—Production-related solid and hazardous wastes are a consideration. Expanded camelina oil production may generate more meal and process wastes than the secondary markets can absorb, though beneficial meal properties may mitigate this consideration. Increased input and processing chemicals used for cultivation, oil extraction, and HEFA production will generate wastes that need to be minimized, reused, and properly disposed of to avoid becoming a compliance burden, legal liability, or negative environmental concern.

Biological Resources—Feedstock cultivation is a potential benefit for biodiversity as camelina is currently viewed as a rotation cover crop cultivated on existing agricultural lands. However, expansion to CRP lands or other habitat conversions could make this a concern as this could decrease habitat availability and impact biodiversity. Conversely, moderate thinning and application of best management or conservation practices can proactively augment habitat that can result in greater species diversity and abundance. New or expanded oil extraction facilities, biorefineries, and distribution infrastructure would require construction and land disturbance. As such, this would be a consideration across stages 2, 3, and 4.

Social

Food Security—Camelina oil, while edible, is not considered a food crop. Furthermore, its production as a fallow cover crop would seem to have minimal food crop displacement, absent expansion to other cropping systems and land. EPA’s RFS2 review likewise confirms the view that direct land use impacts are expected to be negligible and did not expect indirect impacts on other crops.⁶³ Expanded camelina oil production, the resultant increase in meal co-product, may actually be a benefit to livestock feed and food security in stages 1 and 2.

Quality of Life—Expanded production of camelina, camelina oil, and biofuel is a benefit. Increasing fallow land under cultivation, new oil extraction plants, and

⁶¹ Ibid.

⁶² Ibid.

⁶³ Ibid.

new biorefineries would provide agricultural and chemical industry employment opportunities. Camelina cultivation would also not require significant retraining of existing workers as it is analogous to other oil seed crop production systems.

Safety and Health—Increased camelina production would not seem to pose a direct safety and health concern more than other annual row crops and reduced chemical inputs may be a benefit. However, significantly expanded oil extraction in both scope and location could increase occupational and community exposure to hexane solvent air emissions during oil extraction operations. Likewise, new biorefinery employees and surrounding communities could face chemical exposure safety and health hazards similar to existing petrochemical refineries. However, greater biofuel use and combustion may conversely reduce health concerns and burden by reduced air emissions and improved air quality.

Appendix B

Indicator Technical Sheets

The proposed biofuel sustainability architecture requires the development of indicator technical sheets to define the indicator, its relevance, applicable metrics, calculation approach, and risk thresholds. To date, the study had developed a total of thirteen indicator technical sheets that include:

- ◆ Fuel Production Cost and Price (draft)
- ◆ GHG Emissions (revised draft)
- ◆ Air Quality (draft)
- ◆ Stratospheric Ozone Depletion (revised draft)
- ◆ Water Quantity (revised draft)
- ◆ Water Quality (revised draft)
- ◆ Direct Land Use (revised draft)
- ◆ Soil Quantity (revised draft)
- ◆ Soil Quality (draft)
- ◆ Nutrient Requirements and Fertilizer Use (revised draft)
- ◆ Pesticides Use (draft)
- ◆ Invasive Species (revised draft)
- ◆ Direct Food Security (draft).

Fuel Production Cost and Price

Pillar	Economic
Criteria	Cost and Price
Indicator	Fuel Production Cost and Price

After operational fuel suitability, cost-effective production and price competitiveness are the second go-no gate for biofuel sustainability. This key indicator focuses on biofuel production costs versus prices of conventional petroleum-based fuels, and, ultimately, the economic viability of a given biofuel pathway. Detailed, investment grade business cost models are required for the private equity due diligence that would need to be done before financing of the substantial capital expenditures for new biorefineries. In short, if feedstock suppliers and biofuel producers are unable to cover costs, pay debt service, and make a margin, they will not produce the drop-in biofuels the military services and commercial aviation desire. In that case, the environmental and social pillars and criteria assessment will be largely irrelevant as the pathway’s benefits, considerations, and concerns will never materialize.

Given varying levels in the technological maturity of alternative fuel supply chains, the cost effectiveness of any alternative fuel pathway needs to be understood and evaluated using metrics calculated or estimated at commercial scale production.^{1,2} Otherwise, comparing the relative costs and pricing structures of a mature petroleum fuel production supply chain (including its own subsidies, such as accelerated depreciation) to pilot and demonstration-scale production will not generate useful “apples-to-apples” cost assessments. Bulk fuel price is determined by the petroleum and fuel commodity spot markets (supply and demand dynamics driven in large part by cost of production). DLA Energy’s operational fuel [jet propellant (JP)-8, JP-5, F-76] procurements for the military services reflect these markets, with a slight price premium, for mil-spec fuels.

¹ DoD, Opportunities for DoD Use of Alternative and Renewable Fuels, 2011, http://energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf.

² In the absence of existing commercial scale facilities and data, DOE OBP has developed specific methodologies for estimating the cost factor reductions, such as to capital expenditures for “N+1” plants that may be available for government use under strict non-disclosure agreements. Likewise, DARPA Biofuel Program and phase 1 DPA production cost models can calibrate these commercial scale estimates. Industry sources, such as Commercial Aviation Alternative Fuels Initiative SMEs, may be able to further validate projected cost factors.



Fuel production costs are influenced by many of the criteria and indicator areas captured under the four sustainability pillars. However, these costs are directly driven by material and energy inputs, operating expenses, and capital requirements. Furthermore, comparisons of the production cost to the pertinent market price essentially determine any given fuel's economic viability.

RELEVANCE AND RATIONALE

National and military interest in drop-in biofuels has been driven by the potential benefits of promoting national energy security and independence, spurring economic development and jobs, and reducing negative environmental impacts. With American Society for Testing and Materials approval and the certification of certain drop-in biofuels for many weapons platforms, the military services' desire for domestically sourced alternative operational fuels has been proven technically feasible. However, the linchpin is the ability to be cost competitive at commercial scale production. All of the military services' alternative fuel goals currently include caveats requiring cost competitiveness prior to commercial scale purchases.

Table B-1 identifies the wide array of statutes and policies that touch upon and are relevant to reducing biofuel production costs and realizing the goal of price parity.

Table B-1. Fuel Cost and Price Statutory and DoD Policy Relevance

	General relevance	Direct relevance
Statutory and Regulatory Relevance		
Biomass Research and Development Act of 2000		Yes
2002 Farm Bill		Yes
EISA of 2007		Yes
Food, Conservation, and Energy Act of 2008		Yes
Clean Air Act	Yes	
DoD and Service Policy Relevance		
Army Sustainability Report 2010	Yes	
Air Force Energy Plan 2010	Yes	
Navy Energy Vision for the 21st Century	Yes	

From US Congressman, to military service Secretaries, and DLA Energy procurement specialists, there is keen interest in realistic production costs and price competitiveness with conventional bulk fuels. It is "the concern" for industry and

a topic covered in several biofuel sustainability frameworks, approaches, and standards (Table B-2).

Table B-2. Fuel Cost and Price in Sustainability Frameworks and Standards

	Indicator
MOU between US Navy, DOE, and USDA	Yes
DOE Biomass Program, Sustainability Platform	Yes
ORNL, Center for BioEnergy Sustainability	Yes

METRICS SELECTED

Biofuel production cost metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for quantitative comparisons among drop-in biofuels. At a minimum, the following metrics are required to first estimate biofuel cost per gallon; and second, the prices of conventional fuels that determine its cost competitiveness.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Fuel Production Cost, \$/gallon
 - Material Input Costs, \$/gallon
 - Energy Input Costs, \$/gallon
 - Operating Expenditures (OPEX), \$/gallon of capacity
 - Capital Expenditures (CAPEX), \$/gallon of capacity
 - Taxes, \$/gallon of capacity
- ◆ Metric 2: Co-Product Value, \$/gallon of capacity
 - Co-Product Yield, percent
 - Co-Product Value, \$/gallon discount

Sensitivity (Consequence Metrics)

- ◆ Metric 3: Regional Petroleum Fuel Price, \$/gallon

Risk Reduction (Mitigation Metrics)

- ◆ Metric 4: Incentives, Grants, Credits, and RINs, \$/gallon (of capacity).

Applicability of cost and price has been reviewed for each relevant biofuel life-cycle step (stages 1–4). Table B-3 summarizes the applicability findings.

Table B-3. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Fuel Production Cost	Yes	Yes	Yes	Minimal	No
Metric 2: Co-Product Value	Yes	Yes	Yes	Minimal	No
Metric 3: Regional Petroleum Fuel Price	Yes	Yes	Yes	No	No
Metric 4: Incentives, Grants, Credits, and RINs	Yes	No	Yes	Minimal	Yes

MEASUREMENT AND ANALYSIS APPROACH

Cost and price metrics have been identified and selected to provide relevant, representative economic viability comparisons among various drop-in biofuels. These metrics were selected on the basis of recent biofuel studies,^{3,4} outreach conversations with government and industry personnel,⁵ and industry-oriented comparative calculation tools.⁶ At a minimum, these metrics were developed for commercial scale pathways to: 1) provide consistent estimates of biofuel feedstock and conversion pathway production costs; 2) assess the relative regional petroleum prices; and 3) identify subsidies or tax incentives, such as RIN credits, loan guarantees, or technology grants, which can be applied to reduce the costs.

Metric 1: Fuel Production Cost (*National or Local Levels*)

Metric 1 estimates the life-cycle stage costs to produce a gallon of biofuel prior to stage 5. The primary focuses are the stages 1–3 production costs of neat drop-in biofuels. Biofuel distribution, stage 4, costs for blended fuels distribution are considered but should largely be analogous to conventional petroleum, particularly when produced at a commercial scale and distributed via existing pipeline and bulk terminal infrastructure. While proprietary investment grade cost models will include more detail, the main elements for calculating national-level fuel production costs will at a minimum require:

³ DoD, Opportunities for DoD Use of Alternative and Renewable Fuels, 2011, http://energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf.

⁴ Bhargava, A., Drop-in replacement biofuels: meeting the challenge, Sloan School of Management, MIT, 2011.

⁵ Personal Communication with DARPA and DOE OBP personnel, 2011–2012.

⁶ Biofuels Digest, Biofuels Venture Value Calculator, What's your biofuels venture worth?, 2012, <http://www.biofuelsdigest.com/bdigest/2012/03/23/whats-your-biofuels-venture-worth/>.

-
- ◆ Material input costs, \$/gallon
 - ◆ Energy input costs, \$/gallon
 - ◆ OPEX, \$/gallon of capacity
 - ◆ CAPEX,⁷ \$/gallon of capacity (at commercial scale)
 - ◆ Taxes, \$/gallon of capacity
 - ◆ Target profit margin, \$/gallon.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ USDA, Economic Research Service (ERS), Commodity Costs and Returns (<http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx>)
- ◆ USDA, ERS, Oil Crops Outlook Report and Yearbook (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290>)
- ◆ DOE ANL's, GREET Model, Inputs and Conversion Efficiencies (<http://greet.es.anl.gov>)
- ◆ DoD, Opportunities for DoD Use of Alternative and Renewable Fuels, (http://energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf)
- ◆ Biofuels Digest, Biofuels Venture Value Calculator (<http://www.biofuelsdigest.com/bdigest/2012/03/23/whats-your-biofuels-venture-worth/>)
- ◆ DARPA Biofuel Program Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DOE OBP Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DPA Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DLA Energy Vendor Data Packages
- ◆ US EIA, Gasoline and Diesel Fuel Update (<http://www.eia.gov/petroleum/gasdiesel/> and http://www.eia.gov/petroleum/gasdiesel/dieselpump_hist.cfm).

⁷ CAPEX should incorporate depreciation rate and capital finance costs (debt or equity).

USDA ERS conducts monthly and annual surveys of agricultural production, supply, prices, and other data necessary for assessing agricultural and pre-processing operations at both the regional and national levels. Their monthly data and annual outlook reports provide historical and current data on production, use, and prices for existing commodity crops. GREET compiles similar national average inputs and yield data as well as the conversion efficiencies between each stage and step, which are necessary to calculate input quantities and costs on a per gallon basis. In addition, stages 2, 3, and 4 costs should be rolled up and incorporated into the fuel production cost estimates.

These fuel production cost elements are compiled to the level of the metric components identified above across stages 1–4. Agricultural and intermediate product market commodity prices should be used where applicable. Detailed cost models can be developed in cases where such data is unavailable, such as in the case of emergent feedstocks. Neat biofuel production expenses can be estimated from industry cost and CAPEX estimates, federal pilot and technology transition program business models, or proprietary data provided by vendors.

Once all assumptions have been reviewed and the appropriate cost estimates compiled, this metric should be evaluated against production costs and prices of petroleum to determine the likelihood of hazard. Table B-4 presents hazard thresholds based on comparison with convention petroleum fuel production costs/allocated prices based upon EIA calculations.

Table B-4. Fuel Production Cost Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	≤90% cost/price of comparable conventional production
Low	2	90–100% cost/price of comparable conventional production
Moderate	3	>100–125% cost/price of comparable conventional production
High	4	>125–150% cost/price of comparable conventional production
Highest	5	>150% cost/price of comparable conventional production

Metric 2: Co-Product Value (*National or Local Levels*)

Metric 2 is intended to identify and account for co-product generated during biofuel production, particularly in stages 1–3. For example, stage 2 oil extraction in the soybean oil derived hydroprocessed esters and fatty acids pathway generates soy mill and hull co-products that have economic value for food and fiber purposes. Co-products effectively “discount” the production of feedstocks, intermediates, and neat fuels. Two required items to account for this metric include:

- ◆ Co-product yield, percent (of feedstock, intermediate, or product)
- ◆ Co-product value, \$/gallon discount.

Key measurements, databases, and tools for calculating Metric 2 include:

- ◆ USDA, ERS, Commodity Costs and Returns (<http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx>)
- ◆ USDA, ERS, Oil Crops Outlook Report and Yearbook (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290>)
- ◆ DOE, ANL, GREET Model, Inputs and Conversion Efficiencies (<http://greet.es.anl.gov>)
- ◆ EIA, Refinery Yields (http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_m.htm)
- ◆ Biofuels Digest, Biofuels Venture Value Calculator (<http://www.biofuelsdigest.com/bdigest/2012/03/23/whats-your-biofuels-venture-worth/>)
- ◆ DARPA Biofuel Program Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DOE OBP Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DPA Business Models (proprietary data, government non-disclosure agreements required)
- ◆ DLA Energy Vendor Data Packages.

Proper co-product allocation approaches are well debated within the life-cycle inventory and analysis communities. Three of the most common allocation methods (percentages) are on the basis of energy content, dry weight or volume, or economic value. For purposes of this approach, the default priority for co-product allocation should be applied in that order and carefully documented in the analysis.

Once the co-product discount is determined, it should be subtracted from Metric 1 production cost estimates. The resulting sum should then be evaluated using the thresholds presented in Table B-4.

Metric 3: Regional Petroleum Fuel Price (*Regional and Local Levels*)

In Metrics 1 and 2, conventional petroleum fuel price is incorporated as part of the hazard thresholds. However, there are significant differences between average US petroleum fuel prices and regional retail prices. Metric 3 is intended to capture

and integrate these differences as a consequence metric. In doing so, it will help calibrate the regionally specific consequence of biofuel production costs, profit, and market price as this would change economic viability risk, particularly where marginal price premiums exist.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ EIA, Gasoline and Diesel Fuel Update (<http://www.eia.gov/petroleum/gasdiesel/> and http://www.eia.gov/petroleum/gasdiesel/dieselpump_hist.cfm)
- ◆ EIA, Petroleum Marketing Monthly, Taxes by Petroleum Administration for Defense (PAD) District (<http://www.eia.gov/petroleum/marketing/monthly/pdf/enote.pdf>)
- ◆ DLA Class III Fuel Prices by Region (internal procurement data).

Access the current EIA Gasoline and Diesel Fuel Update data for the US and PAD district of interest. Where possible, tax costs should be accounted for and adjusted at the PAD district or state level. Divide the PAD district's price for diesel by the US price. Assess the resulting percentage against the graduated thresholds presented in Table B-5.

Table B-5. Regional Petroleum Fuel Price Thresholds

Sensitivity	Assessed value	Threshold
Lowest	1	≤100% of PAD region price versus US average
Low	2	>100–105% of PAD region price versus US average
Moderate	3	>105–110% of PAD region price versus US average
High	4	>110–115% of PAD region price versus US average
Highest	5	>115% of PAD region price versus US average

Where practical, this metric should be applied to the regional price of Class III operational fuels and account for the DLA-provided logistic costs avoided.

Metric 4: Incentives, Grants, Credits, and RINs (*National or State Levels*)

Metric 4 is intended to account for the mitigation of feedstock and fuel production cost hazard via incentives, grants, or market RINs, which have been authorized under a variety of statutes, such as the EISA of 2007, DPA, and others. These authorized programs represent a range of subsidies intended to encourage production. While each pathway may be eligible for different programs, it is likely that at least some of the various subsidies will apply. The challenge is to accurately estimate the resulting cost reduction per gallon. The types of subsidies available can include the following:

-
- ◆ Material input, \$/gallon
 - ◆ CAPEX grants or financing costs, \$/gallon of capacity
 - ◆ Tax credits, \$/gallon
 - ◆ Regulatory compliance and credits, \$/gallon
 - ◆ Blender payments, \$/gallon.

Key starting resources for calculating Metric 4 include:

- ◆ DOE, EERE, Alternative Fuels Data Center, Federal Incentives and Laws (http://www.afdc.energy.gov/laws/fed_summary)
- ◆ Advanced Biofuel Feedstock Incentives (<http://www.afdc.energy.gov/laws/law/US/10292>)
- ◆ Advanced Biofuel Production Grants and Loan Guarantees (<http://www.afdc.energy.gov/laws/law/US/8502>)
- ◆ Advanced Biofuel Production Payments (<http://www.afdc.energy.gov/laws/law/US/8503>)
- ◆ RFS2, RIN (<http://www.epa.gov/otaq/fuels/renewablefuels/epamts.htm>)
- ◆ DOE, ANL, GREET Model, Inputs and Conversion Efficiencies (<http://greet.es.anl.gov>).

Metric 4 represents perhaps some of the most complex content and calculations of the entire exercise. Each feedstock, conversion, and production pathway will require careful techno-economic analysis of the supply chain, but, moreover, a skillful review to determine the applicability of incentive, grant, tax credit, and RIN market values for stages 1, 3, and 4 of a particular pathway. Likewise, renewable diesel products may qualify while jet fuel products may not. Once eligibility is determined, the applicable incentives, cost reductions, credits, and payments are to be applied to the adjusted production cost estimates calculated in Metric 2. These reductions, credits, and payments are to be applied and subtracted. The market value of the appropriate advanced biofuel RINs should be estimated and likewise applied as a reduction to the production cost line.

After these cost reductions are applied, the life cycle and total cost and price estimates are to be evaluated against the thresholds presented in Table B-6. This revised likelihood rating should be used to calculate the mitigated cost and price risk for the pathway.

Table B-6. Incentives, Grants, Credits, and RINs Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	≤90% of comparable conventional product price
Low	2	>90–100% of comparable conventional product price
Moderate	3	>100–125% of comparable conventional product price
High	4	>125–150% of comparable conventional product price
Highest	5	>150% of comparable conventional product price

General Considerations, Assumptions, and Uncertainties

In all of these metrics, assumptions must be identified, made explicit, carefully reviewed, and compared to ensure robust and consistent calculations. Uncertainty related to these assumptions and interactions with dynamic commodity markets need to be carefully identified and described. To better understand the interactions, sensitivity analysis should be performed and potentially illustrated through the use of scenarios. Furthermore, general techno-economic analysis inputs and calculations will quickly become dated due to a rapidly maturing biofuels industry and a volatile petroleum fuel market place. As such, it is recommended that the analysis be revisited at least on an annual basis, if not quarterly.

RESOURCES AND SMES

Keystone Resources

Bhargava, A., Drop-in replacement biofuels: meeting the challenge, Sloan School of Management, MIT, 2011

Biofuels Digest, Biofuels Venture Value Calculator, What's your biofuels venture worth?, 2012, <http://www.biofuelsdigest.com/bdigest/2012/03/23/whats-your-biofuels-venture-worth/>

DoD, Opportunities for DoD Use of Alternative and Renewable Fuels, 2011, http://energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf

DOE, ANL, GREET Model, Inputs and Conversion Efficiencies, <http://greet.es.anl.gov>

Identified SMEs and Organizations

Mr. Brian Duff, OBP, DOE

Mr. David Brinkley, Manufacturing and Industrial Base Policy, OSD, DoD

Dr. Jim Hileman, FAA

Mr. Aaron Levy, OTAQ, EPA

Dr. Robert Mantz, Biofuel Program, DARPA

Dr. Michael Wang, ANL, DOE

REFERENCES

Bhargava, A., Drop-in replacement biofuels: meeting the challenge, Sloan School of Management, MIT, 2011.

Biofuels Digest, Biofuels Venture Value Calculator, What's your biofuels venture worth?, 2012, <http://www.biofuelsdigest.com/bdigest/2012/03/23/whats-your-biofuels-venture-worth/>.

Deconti, Mario, Estimating the Cost-effectiveness of Biofuels, Economics Group, Department for Environment, Food and Rural Affairs, UK, April 2008, <http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/explained/bioenergy/biofuels/biofuels-080414-2.pdf>.

DoD, Opportunities for DoD Use of Alternative and Renewable Fuels, 2011, http://energy.defense.gov/NDAA_FY10_Sec_334_Report_FINAL_85B3.pdf.

DOE, ANL, GREET Model, Inputs and Conversion Efficiencies, <http://greet.es.anl.gov>.

EIA, Gasoline and Diesel Fuel Update, <http://www.eia.gov/petroleum/gasdiesel/>.

EIA, Refinery Yields, http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_m.htm.

Radich, Anthony. Biodiesel Performance, Costs, and Use, EIA, <http://www.eia.gov/oiaf/analysispaper/biodiesel/>.

Steenblik, Ronald, Biofuels—At What Cost? Global Subsidies Initiative, International Institute for Sustainable Development, September 2007, <http://www.iisd.org/gsi/sites/default/files/oecdbiofuels.pdf>.

USDA, ERS, Commodity Costs and Returns, <http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx>.

USDA, ERS, Oil Crops Outlook Report and Yearbook, <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290>.

Yii-Der You et al., Economic Cost Analysis of Biodiesel Production: Case in Soybean Oil, *Energy Fuels*, 2008, 22 (1), pp 182–189, October 2, 2007, <http://pubs.acs.org/doi/abs/10.1021/ef700295c>.

GREENHOUSE GASES EMISSIONS

Pillar	Environmental
Criteria	Air
Indicator	Greenhouse Gases - Direct Emissions

GHGs emissions are generally considered to refer to the release of CO₂, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride into the atmosphere. A biofuel's life-cycle GHG include the aggregate emissions from feedstock production, feedstock transport, biofuel production, transportation, and use. According to EISA 2007, Section 201, life-cycle GHG includes both "direct emissions and significant indirect emissions such as significant emissions from land use changes" and goes further to define classes of biofuel according to their percentage of reductions in life-cycle GHG emissions relative to a petroleum fuel baseline.⁸

Life-cycle GHG emissions are applicable at a global scale and do not have directly attributable regional or local effects (known to date). However, the life-cycle GHG indicator does depend upon and feed into other indicators' areas (Figure B-1).

Figure B-1. GHG Indicator Relationships



For example, biofuel life-cycle GHGs include direct changes in land use when they are required for feedstock cultivation, processing, and biofuel production. Although soil and plants sequester CO₂, sequestered emissions are released and amortized when land is converted for use in cultivation of the biofuel feedstock. Land use changes can be direct, via the conversion of land for cultivation, or indirect, when conversion of land leads to new land use patterns in another location. This land use change can be a "significant" part of the life-cycle GHG emissions of biofuels. However, for purposes of this assessment, we segregate direct and significant indirect life-cycle GHG for sake of transparency due to

⁸ According to CEQ's Federal Greenhouse Gas Accounting and Reporting Guidance, "CO₂ emissions resulting from combustion of biomass and biofuels are known as biogenic emissions...Part or all of the carbon in these fuels is derived from material that was fixed by biological sources on a relatively short timescale." As such, it is for all practical purposes a separate GHG that is considered and often reported separately. While its reporting is still maturing, biogenic CO₂ is generally zeroed out or reported separately when calculating GHG emissions so clarification should be gained as to how this is handled within a particular life-cycle GHG study or model.

boundary definitions and uncertainty differences. As greater scientific consensus emerges, a separate “life-cycle GHG-indirect” indicator technical sheet would be developed and proposed.

Relevance and Rationale

The life-cycle GHG indicator is one of the most dominant environmental issues mentioned throughout US biofuel statutes, US Government (USG) policies, and DoD policies. Table B-7 highlights statutes and policies where life-cycle GHG indicators are relevant.

Table B-7. GHG Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
Biomass Research and Development Act of 2000		Yes	
2002 Farm Bill		Yes	
Energy Policy Act of 2005	Yes		
EISA of 2007		Yes	Yes
National Environmental Protection Act of 1970	Yes		
Clean Air Act	Yes		
USG Policy Relevance			
EO 13423	Yes		
EO 13514	Yes		
OMB Scorecard		Yes	
DoD and Service Policy Relevance			
DoD Strategic Sustainability Performance Plan FY10	Yes		
DoD Strategic Sustainability Performance Plan FY11	Yes		
Air Force Energy Plan 2010	Yes		
Navy Energy Vision for the 21st Century		Yes	

From a federal judicial perspective, the US Supreme Court (*Massachusetts v. EPA*) ruled in 2007 that air pollutants covered under the CAA do include GHGs. In December 2009, the EPA Administrator released both an “endangerment finding” and a “cause or contribute finding” regarding GHGs, which has triggered new regulatory scrutiny already impacting existing air regulations and regimes. Through actions such as the EPA “Tailoring Rule,” GHG production emissions could represent supply chain risks or costs added along to the fuel. However, at the state level, Federal District Court rulings have challenged the legality of the California Low Carbon Fuel Standard⁹ in December 2011 for Constitutional

⁹ <http://biofuelsdigest.com/bdigest/2011/12/30/us-federal-court-issues-injunction-against-california-low-carbon-fuel-standard/>.

overreach in its regulatory and economic use of life-cycle GHG models of biofuels. While there is still uncertainty on the judicial front, a life-cycle GHG indicator is necessary for compliance with EISA Section 526 and impacts the economic incentives under RFS2 as a function of biofuels' classification.

Outside of the federal statutory and state regulatory framework, concern over biofuels' GHG characteristics is ubiquitous across virtually every agency sustainability framework, approach, and industry standard (Table B-8).

Table B-8. GHG Indicators in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
DOE Biomass Program, Sustainability Platform	Yes	
DOE, ORNL, Center for BioEnergy Sustainability Indicators	Yes	Yes
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	Yes
Global Bioenergy Partnership, Sustainability Indicators	Yes	Yes
ISO 14025, Product Category Rules	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

Of these frameworks, many of the federal agencies seem to be considering the use of ANL's GREET model and/or EPA OTAQ GHG LCA approaches and models. International or industry standards have likewise been developing their own life-cycle GHG estimation guidance, boundary conditions, methodologies, and tools. For example, GBEP and the RSB both have developed life-cycle GHG methodology resources and even an RSB tool.

Given its presence throughout statutes, policy, and standards, the rationale for incorporating a life-cycle GHG indicator is that it is first a compliance requirement. Second, failing to consider life-cycle GHG metrics and perform analysis would represent both supply chain and service client acceptance risks unacceptable to DLA Energy.

Metrics Selected

Life-cycle GHG emission metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for quantitative comparisons among drop-in biofuels. At a minimum, the follow metrics are required to: 1) ensure compliance with EISA Section 526; and 2) qualification as an RFS2 renewable, biomass-based, or cellulosic fuels that generates RINs.

Pathway Characteristic (Likelihood Metrics)

- ◆ Metric 1: GHG Direct Emissions, grams (g) CO₂e/megajoule (MJ) biofuel
- ◆ Metric 2: Biogenic CO₂ Direct Emissions, g CO₂/MJ biofuel
- ◆ Metric 3: GHG Indirect Land Use (ILUC) Emissions, g CO₂e/MJ biofuel
- ◆ Metric 4: GHG Intensity Section 526 Compliance, ratio of biofuel GHG intensity over 2005 petroleum fuel baseline
- ◆ Metric 5: GHG RFS2 Eligibility, % reduction over baseline

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Not Currently Defined–Uncertain Science

Risk Reduction (Mitigation or Management Metrics)

- ◆ Metric 6: Carbon Sequestration or Reuse, low heat value (LHV) g CO₂e/MJ biofuel.

Life-cycle GHG emissions metrics 1–5 are currently applicable and calculated across the entire fuel life cycle.¹⁰ If applicable, metric 6 should be applied at the appropriate life-cycle stage.

Table B-9. Metric Relevance by Life-cycle Stage

Life-cycle Stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: GHG Direct	Yes	Yes	Yes	Yes	Yes
Metric 2: Bio-genic CO ₂ Direct	Yes	Yes	Yes	Yes	Yes
Metric 3: GHG ILUC	Yes	Yes	Yes	Yes	Yes
Metric 4: GHG Intensity	Yes	Yes	Yes	Yes	Yes
Metric 5: RFS2 Eligibility	Yes	Yes	Yes	Yes	Yes
Metric 6: Se-questration or Reuse	Yes	No	Yes	No	No

¹⁰ Wang, Michael, 2011, Overview of Life-Cycle Analysis with the GREET Model, The GREET Training Workshop, ANL, December 7–8, 2011, Systems Assessment Group, Center for Transportation Research, ANL, http://greet.es.anl.gov/event-workshop_dec_2011.

Variations in life-cycle boundaries, co-product allocation methodologies, and assumption largely characterize the differences in approaches and results, despite that these “mostly attributional” life-cycle inventories and models are based on the ISO 14040 series of standards for life-cycle analysis. For example, direct GHG emission estimates may be greatly influenced by whether pesticides production is included, or whether ILUC is considered in the LCA.

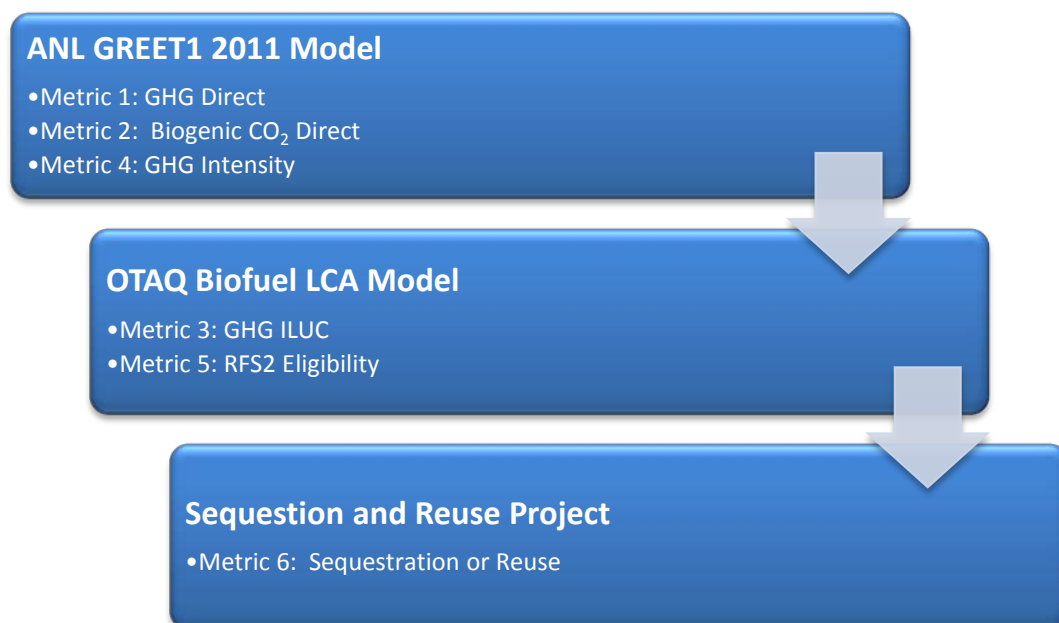
Modeling Approach

While there are several protocols, reporting guidance, and LCA standards, it is recommended that these metrics be calculated using the approaches and best practices of the ISO 14040 series and the Interagency Working Group guidance titled “Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels.” As discussed earlier in the report, the level¹¹ of LCAs vary and the output metrics should be determined by its end use, such as generating research and development inputs (Level III), screening Service-sponsored operational demonstrations (Level III and II), or evaluating specific biofuels procurements (Level II & I) for compliance with EISA or RFS2 biofuel category.

To generate the selected metrics, a minimum of two models are applied to meet DLA Energy’s needs, DOE ANL’s GREET 1 2011 platform and EPA OTAQ’s LCA models (Figure B-2). Unlike many indicator metrics, these metrics and methods are largely unchanged in moving from a national screening level LCA, to regional operational demonstrations, or even a biofuel specific life-cycle GHG analysis. These LCAs would largely differ only in the level of data detail and geographic and technological fidelity as consequence metrics are not currently available for this indicator.

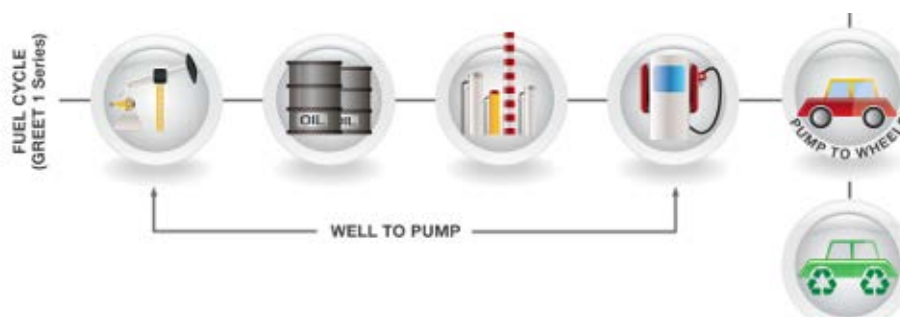
¹¹ There are generally three levels of LCA’s that include: Level I: Comprehensive, Level II: Standard, Level III: Screening. These vary in the process fidelity and data detail and serve different end uses given the level of accuracy reflected in the results.

Figure B-2. GHG Models and Means to Metrics



GREET1 2011

First released by ANL in 1996, GREET evaluates the energy and emissions implications of transportation fuels and vehicle technologies across their life cycle. Over the last 15 years, this attributional LCA model was expanded into one of the leading life-cycle fuel and transportation models. GREET is compiled in a “multidimensional spreadsheet model in Microsoft Excel” and is available free of charge.¹² ANL plans to update this workbook version and deploy to a web-based architecture.¹³ GREET enables researchers and analysts to evaluate different fuel and vehicle combinations across fuel-cycle (stages 1–4) thru vehicle use (stage 5). Figure B-3 illustrates this scope.

Figure B-3. GREET1 2011 Fuel Cycle Scope^a

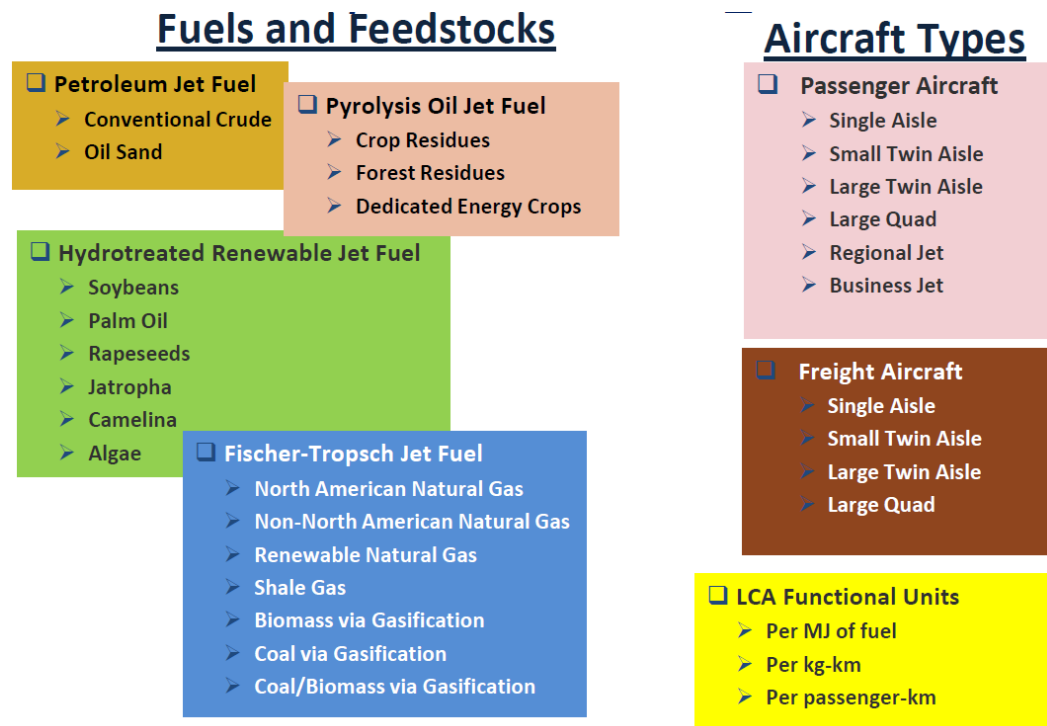
Wang, 2011, Overview of Life-Cycle Analysis with the GREET Model, GREET Training Workshop, December 2011.

¹² <http://greet.es.anl.gov/main>.

¹³ http://greet.es.anl.gov/event-workshop_dec_2011.

With its 2011 update, GREET expanded to over 100 pathways, including aviation fuels and several drop-in biofuel pathways, such as algae, cellulosic pyrolysis, etc. DLA-FAA joint work program supported the development of this expansion with the GREET for jet effort. Figure B-4 highlights these added jet fuel oriented capabilities.

Figure B-4. GREET1 2011 Jet Fuel Capabilities



Wang, 2011, Overview of Life-Cycle Analysis with the GREET Model, GREET Training Workshop, December 2011, http://greet.es.anl.gov/event-workshop_dec_2011.

GREET draws and compiles data from a broad variety of resources. In addition to DOE sources, it has incorporated authoritative emission factors and fuel product specifications. Likewise, its development and research has resulted in model reports, presentations, technical reports, and journal articles. Using this compiled data, GREET's analysis produces fuel life-cycle results for energy/fuel use, criteria air pollutants, and GHG. Within these three results categories, it is possible to generate metrics, such as:

- ◆ Energy use (total energy, fossil energy and renewable energy, petroleum, natural gas, and coal)
- ◆ Criteria air emissions (CO, S_{ox}, NO_x, PM2.5, PM10, and VOCs)
- ◆ GHGs emissions (CO₂, CH₄, N₂O, CO_{2e})

- ◆ Total emissions and urban emission subset.¹⁴

The GREET model can also increasingly integrate consequential LCA inputs, such as indirect land use. The addition of the Carbon Calculator for Land Use Change from Biofuels Production (CCLUB) modeling capabilities can potentially be used to fulfill metric calculation needs for this indicator.¹⁵

EPA OTAQ LCA MODEL

Section 201(1)(H) of EISA 2007 required EPA to consider direct life-cycle GHG emissions from biofuels as well as “significant indirect emissions such as significant indirect land use changes.” EPA is responsible for the RFS2 program and for assessing its regulatory impact within the context of this legislative mandate. To support their rulemaking process, EPA needed to develop a new life-cycle GHG methodology as the models existing at the time would not address the entirety of EISA life-cycle GHG mandate. To this end, they collaboratively developed a new life-cycle analysis model approach that elaborated in depth within Chapter 2 of the RFS2 Regulatory Impact Analysis.¹⁶

To evaluate transportation biofuel’s GHG impacts for the RFS2 proposed and final rules, EPA OTAQ developed hybrid LCA models that leveraged GREET 1.8c model and two agricultural sector models, FASOM and FAPRI. GREET provided an attributional model structure, data, and emission factor resources for the attributional LCA. EPA researched, compiled, and incorporated additional industry data to incorporate the covered feedstocks and pathways for ground transportation fuels.¹⁷

Given the EISA requirement for the analysis of indirect impacts, EPA leveraged FASOM and FAPRI to address the consequential aspects of this LCA family of models (Figure B-5). Developed by Texas A&M University, FASOM was used to estimate land use changes within the US agricultural sector that was then utilized to calculate the indirect land use change related GHG emissions. FAPRI-CARD was developed by Iowa State University and models the “biological, technical, and economic relationships...within a particular commodity and across commodities.”¹⁸ EPA leveraged this model and its outputs to account for international consequences from increased US biofuel production.

¹⁴ See footnote 3, this appendix.

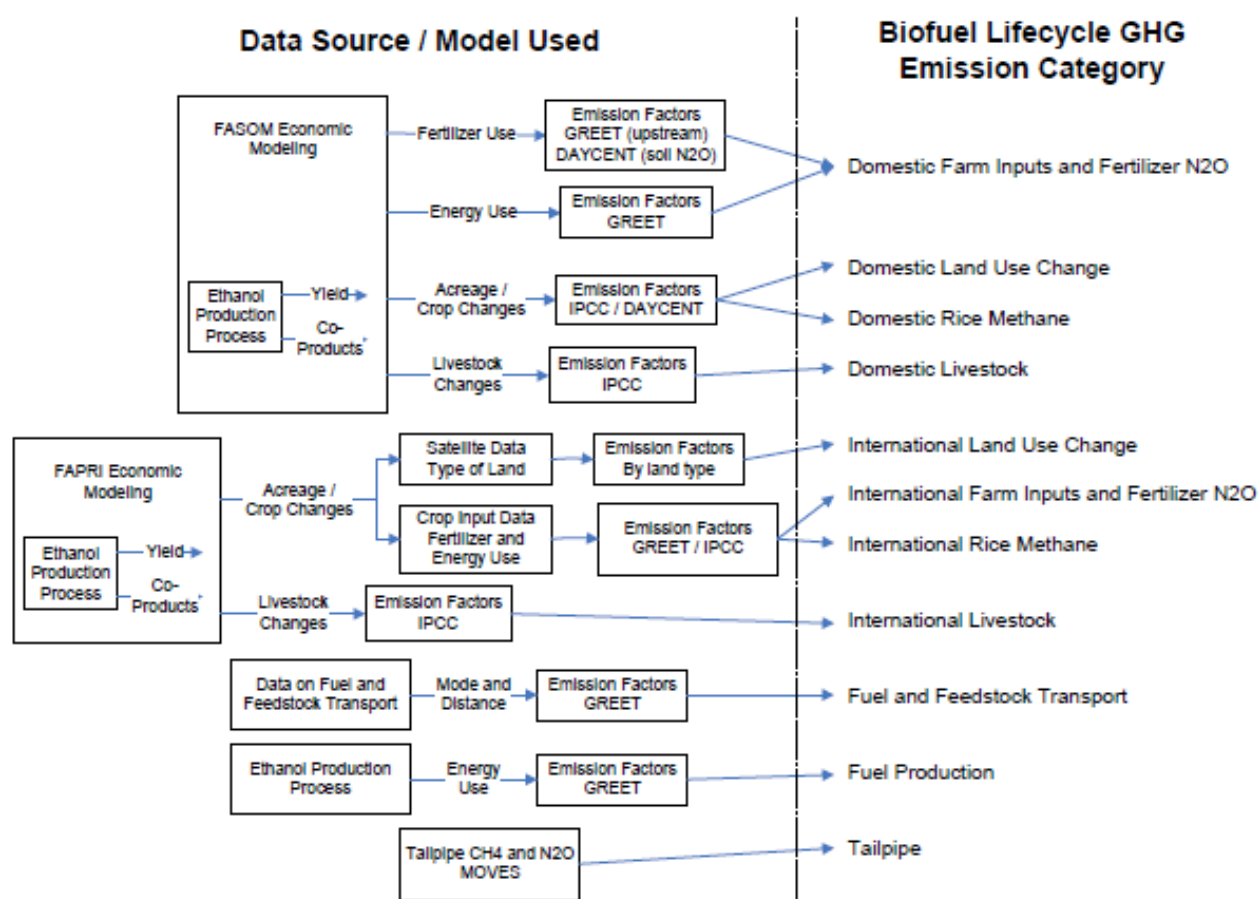
¹⁵ Dunn and Mueller, 2011, Argonne National Laboratory, University of Illinois at Chicago, December 7, 2011, http://greet.es.anl.gov/event-workshop_dec_2011.

¹⁶ EPA, RFS2 Regulatory Impact Analysis, EPA-420-R-10-006, February 2010. <http://www.epa.gov/otaq/renewablefuels/420r10006.pdf>.

¹⁷ Ibid.

¹⁸ Ibid.

Figure B-5. EPA Boundary and Model Summary



EPA, Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis, EPA-420-R-10-006, February 2010, 302, <http://www.epa.gov/otaq/renewablefuels/420r10006.pdf>.

EPA's family of models approach is based in linked MS Excel workbooks. The source data and models are all publicly available, but this analysis is done by EPA SMEs so it remains an in-house federal capability.

While EPA's coverage of feedstocks and biofuels pathways has been limited, EPA OTAQ is responsible for adding and analyzing new feedstock and production pathway when petitioned. For example, in response to industry petitions, EPA released the "EPA Issues Direct Final Rule for Additional Qualifying Renewable Fuel Pathways Under the RFS2 Program" document providing clarification on the applicability of RINs to jet fuels and results of feedstocks, such as camelina, qualification as renewable diesel and jet fuel. These determinations are authoritative life-cycle GHG reduction estimates and have ripple effects on economic pillar indicators because of the qualification for RINs. However, the challenge is the delay in analysis and coverage of emerging drop-in biofuels that could be considered in operational demonstrations or for DPA support.

METRICS 1 AND 2: GHG DIRECT AND BIOGENIC CO₂ DIRECT

Metrics 1 and 2 provide absolute emissions generated across set biofuel life cycles (stages 1–5). Metric 1: GHG Direct Emissions is defined in units of g CO₂e/MJ biofuel using the LHV both by each life-cycle stage and in total across all stages. Metric 2: Biogenic CO₂ Direct Emissions is defined in units of g CO₂/MJ biofuel likewise using LHV but is largely representative of biogenic CO₂ emissions inherent to stage 1.

As direct measure GHG emissions would be technically challenging and highly costly, both of these metrics are generated from the modeled feedstock and fuel pathways generated by the GREET model.

For Level III screening results, go to <http://greet.es.anl.gov/> and download the most recent version of the GREET model (as of this writing the most current version is GREET1_2011). Read the documentation to ensure the feedstock and conversion pathway of interest is present within the GREET version you have downloaded. Go to GREET and extract the results data of each fuel for metric 1. The following locations include the data, by fuel, for each life-cycle stage:

- ◆ Stage 1–4: Location varies by fuel type and requires aggregation by the four stages. The fuel types have different number of steps (g CO₂/mmBtu)¹⁹
 - Petroleum: Tab *Petroleum*, Table 4
 - Soybean, palm, rapeseed, jatropha, camelina: Tab *BioOil*, Table 3
 - Pyrolysis: Tab *Pyrolysis*, Table 3
 - Algae: Tab *Algae*, Table 4
 - Jet: Tab *JetFuel_WTP*, Table 3.1 and 3.2
- ◆ Stage 5: Value is based on distance traveled and not just fuel burned.
 - Ground: Tab *Results*, Tables 2, Column D in g CO₂/mile
 - Jet: Tab *JetFuel_WTW*, Table 2 (g CO₂/kg km)

For jet fuels, ensure the results data selected for stage 5 (biofuel use) represents similar anticipated aircraft types where combusted. If not, obtain the appropriate emission factors for GREET model customization prior to results data extraction. Likewise, if Level II and I LCAs are needed, GREET can be customized with data inputs and mapping to advise operational demonstration plant or product decisions.

¹⁹ Note: Native units of g CO₂e / mmBTU from GREET will be converted to g CO₂e / MJ using conversion factor of 1055.06 (g / MJ) = 1 (g / mmBTU) x 1055.06 (mmBTU / MJ).

While Metric 2 is not explicitly listed in GREET, it is calculated as a negative adjustment value to inherently offset biogenic GHG emissions from the total CO₂ emissions. To calculate and obtain this metric, go to tab *Vehicles* for ground vehicles and tab *JetFuel_WTP* for jet and extract the results data of each life-cycle stage for metric 1.

For ground vehicles, the biogenic value is calculated using the amount of carbon in a specific fuel from the tab *Fuel_Specs*. These emissions are subtracted from the feedstock emission factor in the *Results* tab as g CO₂ per mile.

For jet, the biogenic emissions are built into the stage 1 emission factor in tab *JetFuel_WTP*. In Table B-4 on that tab, the feedstock value in g CO₂/mmBtu includes an equation (row 285). The jet biogenic emission equation does not currently differ between renewable feedstocks, and the emission factor data is available on tab *JetFuel_PTW*.²⁰

The analysis thresholds for these metrics are partially addressed here and, for metric 1, within the discussion of Metric 4. Metric 1 can and should be analyzed against the established petroleum baseline and other biofuel feedstock and conversion pathways found with GREET. While the comparison to the petroleum baseline is largely covered for compliance purposes under Metric 4, threshold levels should be determined for Metric 1 thru a statistical comparison against other drop-in fuel pathways, which can generate “Gaussian” or “normal” distributions and standard deviations. These normal statistical distribution breaks are used to determine vulnerability classifications.

Table B-10. GHG Direct Emission Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	STD -3 to STD -2
Low	2	STD -2 to STD -1
Moderate	3	STD -1 to STD 1
High	4	STD 1 to STD 2
Highest	5	STD 2 to STD 3

These threshold levels should be reassessed and analyzed with every new update to GREET.

For Metric 2, the likelihood or pathway characteristic will be analyzed by generating a percentage of g biogenic CO₂ emitted/MJ of biofuel over total GHG emissions (metric 1 g CO₂e/MJ + g biogenic CO₂ emitted/MJ). This particular metric

²⁰ For example, in row 285 of *JetFuel_WTP*, for camelina the feedstock emission factor sums the emissions associated with creating camelina feedstock (farming, fertilizer, chemicals, and transportation) and subtracts the carbon portion of the fuel burned on a per mmBtu basis. The calculation uses a standard set of SPK characteristics, including its carbon density and the heating value of the SPK.

provides insight into the transition from anthropogenic CO₂ generation to that of biogenic, which is a required element for current federal GHG reporting.

Table B-11. Biogenic Emission Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	100→80% biogenic CO ₂
Low	2	80→60% biogenic CO ₂
Moderate	3	60→40% biogenic CO ₂
High	4	40→20% biogenic CO ₂
Highest	5	20→0% biogenic CO ₂

REET has an extensive list of stated assumptions inherent to the model. These assumptions are provided in the user documentation and source publications available at: <http://greet.es.anl.gov/publications>. Particular attention should be paid to life-cycle boundaries and coverage, assumed energy and emission factors utilized in the Level III assessments, and omissions. For example, REET for Jet pathways omit the CH₄ and N₂O emissions in stage 5 as the scientific literature on their global-warming potential (GWP) impacts at altitude are still under consideration and debate. The model has been previously subject to criticisms, such as data sourcing and methodology documentation.

That being said, sensitivity analyses have been performed on REET's inputs²¹ and can certainly help provide insights into the impact of data input uncertainty on the model's ultimate results. Comparisons against similar components within the EPA LCA can provide a comparative measure to assess the level of model result divergence (i.e., how far off are REET's model estimates from the Level II LCA performed by EPA for RFS2 RIN eligibility?). Furthermore, it is recommended that DLA Energy work with their interagency partners and ANL to evaluate, use and manage data used for these analyses in accordance with CEQ, Federal Greenhouse Gas Accounting and Reporting Guidance, GHG Protocol's Corporate Value Chain (Scope 3) Accounting and Reporting Standard, and other identified best practices.

METRICS 3 AND 5: GHG ILUC AND RFS2 ELIGIBILITY

Metric 3 provides EPA's most current estimate of GHG ILUC Emissions in units of g CO₂e/MJ LHV for a smaller subset of biofuel feedstocks and pathways. This metric combined with EPA's application of a REET derived attributional LCA generates Metric 5 in units of percentage reduction over the petroleum baseline. Metric 5 is significant as it is the statutory basis from EISA 2007 for categorizing and processing biofuel petitions submitted for RFS2 eligibility and the resultant RINs.

²¹ <http://www.transportation.anl.gov/pdfs/TA/141.pdf>.

While direct measurement of any attributional GHG inventory is prohibitively complex and challenging, Metric 3 utilizes scenarios and the FASOM model to produce consequential (or indirect) land use change results, which are subsequently multiplied against emission factors to calculate the stage 1 GHG emission results. In accordance with EISA 2007's mandate and definitions, Metric 5 is generated by EPA OTAQ LCA Model for the purpose of determining whether a particular petitioned, biofuel feedstock and production pathway qualifies as a biofuel under the four biofuel categories and whether the biofuels produced are eligible for RINs. The four eligible biofuel categories are:

- ◆ Type R: Other Renewable Fuels (20–50% GHG reduction)
- ◆ Type A: Other Advanced Biofuels (50% or more GHG reduction)
- ◆ Type B: Biomass-based Diesel (includes jet fuel) (50% or more GHG reduction)
- ◆ Type C: Cellulosic Biofuels (60% or more GHG reduction).

As EPA analyzes and addresses pathway petition, they analyze and provide direct responses to the petitioners, release notices of data availability for specific pathways, and release final rules, such as the “Direct Final Rule to Identify Additional Fuel Pathways under the Renewable Fuel Standard Program (RFS2)” issued in November 2011. For current releases refer to: <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>.

Metrics 3 and 5 are available for any feedstock and biofuel pathway that has been through the petition process. See approved or in-process pathways at: <http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi?YEAR=current&TITLE=40&PART=80&SECTION=1426&SUBPART=&TYPE=TEXT> and <http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm>. If completed, EPA generally releases a notification of availability or direct rule fact sheet. EPA makes its data, modeling, and percent reduction results available at: <http://www.regulations.gov> and <http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm>. However, reach out to the EPA OTAQ point of contact listed below for data, analysis result, or status questions if not readily available on the aforementioned web resources.

Metric 3's primary purpose is to enable its inclusion and use to generate Metric 4, where not available from CCLUB or part of a completed EPA pathway analysis.

However, the analysis of Metric 5, when available, is a key life-cycle GHG metric given its relevance for RIN eligibility and the associated relationship to economic viability indicators. As such, the analysis thresholds reflect the EISA 2007 Sections 202 and 526.

Table B-12. RFS2 Eligibility Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	60% or greater reduction of GHG emissions
Low	2	60–50% reduction of GHG emissions
Moderate	3	50–20% reduction of GHG emissions
High	4	<20–>0% reduction of GHG emissions
Highest	5	0% or less reduction of GHG emissions (not EISA Section 526 compliant)

Key assumptions to consider in the EPA LCA model suite are the boundaries and split between the attributional LCAs and consequential LCA components (i.e., indirect US domestic land use and international land use emissions). Full stated assumptions and scope limitations can be referenced in Chapter 2 of the EPA’s RFS2 Regulatory Impact Analysis.

To help gauge uncertainty in Metric 5, DLA Energy can potentially compare the EPA attributional LCA to those developed in GREET and other similar LCAs (e.g., MIT, etc.). Likewise, Metric 3 results on indirect land use can be compared with CCLUBs and other scenario based models as the science and policy emerge.

METRIC 4: GHG INTENSITY

Metric 4: GHG Intensity is perhaps the most critical measure for this indicator because of its role in assessing EISA 2007, Section 526 compliance. Metric 4 is a ratio of biofuel GHG intensity over 2005 petroleum fuel baseline. While final compliance is determined by the DLA Energy General Council, GHG intensity can be determined easily using the percentage reduction results in Metric 5.

$$\text{Metric 4 GHG Intensity} = \frac{(1 - (\text{Metric 5 \%} \div 100))}{1}$$

However, this simplified approach is only applicable when the specific feedstock and conversion pathway has been previously analyzed for RFS2 and is available from EPA.

When Metric 4 is unavailable, Metric 5 can be calculated using GREET model direct emission results (g CO₂e/MJ) that have been customized to provide a Level II or Level I LCA for the specified biofuel. While a Level I attributional LCAs would be preferred to evaluate Section 526 compliance, Level II LCA may be appropriate in cases where sufficient data and commercial scale production experience do not exist. If so, the needed data requirements should be defined and made

part partner agreements or procurements so uncertainty²² can be monitored and reduced as experience is gained with a particular pathway and biofuel product.

Given the aforementioned EISA Section 201 definition of life-cycle GHG and its requirement to consider “significant indirect emissions such as significant emissions from land use changes,” DLA’s due diligence and adherence to interagency guidance requires the use of a “mostly attributional” LCA that includes consequential LCA model components to address domestic land use change.²³ To this end, Metric 3²⁴ (g CO₂e/MJ) for a comparable pathway should be identified and added to Metric 1. Once identified, the following formula should be used.

$$\text{Metric 4 GHG Intensity} = \frac{(\text{Metric 1} + \text{Metric 3}) \text{ g CO}_2\text{e/MJ}}{2005 \text{ Petroluem Baseline g CO}_2\text{e/MJ}}$$

If not comparable, Metric 3 value is available from RFS2, CCLUB assessment may be used to generate a comparable assessment value, particularly in the absence of scientific and policy agreement over indirect land use accounting.

Metric 4 analysis thresholds are developed from EISA Sections 526 and 202 criteria as with Metric 5 thresholds. These statutory definitions have been expressed in GHG intensity ratios.

Table B-13. GHG Intensity Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Ratio of 0.4 or below
Low	2	Ratio of 0.4–0.5
Moderate	3	Ratio of 0.5–<0.8
High	4	Ratio of 0.8–<1.0 (potential for due diligence dispute)
Highest	5	Ratio of 1.0 or more (not EISA Section 526 compliant)

Aside from the assumptions and limitations stated in the previous metrics, key items to consider for Metric 5 relate to inference bridges or assumptions utilized in a Level II attributional LCA as well as the scenarios and uncertainties inherent in generating, reviewing, and explaining the consequential LCA approach used for indirect land use change. In the latter, given the immaturity and lack of methodological consensus, assumptions, scenarios, and areas of uncertainty should be predominantly stated, considered, and updated as the state of the

²² Key methodological issues, such as co-product allocation, will likewise represent key areas of uncertainty until greater technical consensus is gained and should be explicitly noted.

²³ AFRL, Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels (Final Report), April 2009.

²⁴ DoD policy on the inclusion of indirect land use emissions has not yet been decided. As such, the current inclusion of Metric 3 is for technical completeness and should not be construed as an explicit or implicit policy determination or position on this topic.

science advances. Likewise, operational data and greater experience gained with commercial scale production of drop-in biofuels should be used to refine the attributional models or to generate Level I LCAs.

METRIC 6: SEQUESTRATION OR REUSE

Carbon sequestration and, increasingly, reuse technologies are under development and study within the context of alternative fuels and biofuels. Some of the key-stone research and synthesis has been performed by NETL and interagency working groups^{25,26} on the life-cycle GHG emission implications of various carbon sequestration approaches. Increasingly, the life cycle and GHG accounting implication of using solid waste, waste gas carbon dioxide, and waste gas carbon monoxide sources, particularly for algal feedstock cultivation or waste-gas-to-energy processes (LanzaTech), raises fundamental boundary definition issues. While not biogenic CO₂, should such sources be accounted for as such given their use of carbon that would otherwise be directly emitted to the atmosphere?

Given these uncertainties, Metric 6: Carbon Sequestration or Reuse should be calculated using units of g CO₂/MJ biofuel LHV, where applicable. Data sources can include NETL for generic sequestration technologies under study. However, project design estimates or actual operational data should be used where available, particularly given the lack of widespread commercial scale use and experience.

Using project design or operating data, sequestration or reuse technologies can be applied to and integrated with Metric 4 calculations to generate adjusted GHG intensity measures. The specific thresholds would be identical to those of Metric 4, which include:

Table B-14. Sequestration or Reuse Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Ratio of 0.4 or below
Low	2	Ratio of 0.4- 0.5
Moderate	3	Ratio of 0.5 - <0.8
High	4	Ratio of 0.8 - <1.0 (potential for due diligence dispute)
Highest	5	Ratio of 1.0 or more (not EISA Section 526 compliant)

Methodological uncertainty concerning LCA boundary definition and the handling of carbon reuse situations poses the greatest uncertainty. As waste-to-energy accounting consensus and best practice is achieved, consistent derived methodol-

²⁵ AFRL, Life Cycle Greenhouse Gas Analysis of Advanced Jet Propulsion Fuels: Fischer-Tropsch Based SPK-1 Case Study (Final Report), August 2011.

²⁶ Stratton et al., 2010, Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, Partnership for Air Transportation Noise and Emissions Reduction, Project 28, <http://web.mit.edu/aeroastro/partner/projects/project28.html>.

ologies must be considered and finalized to navigate the complexities of carbon reuse and even operational biofuel definitions.

GENERAL CONSIDERATIONS, ASSUMPTIONS, AND UNCERTAINTIES

While the LCA community is guided by ISO 14040 series and best practices, there is widespread uncertainty and crossover with US federal and non-profit GHG reporting protocols guiding upstream scope 3 GHG emissions, such as the CEQ, Federal GHG Accounting and Reporting Guidance and WRI GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard. Likewise, system level uncertainties, such as differing inventory boundaries or co-product allocation methods, can make LCA's difficult to compare. For new and emerging pathways, technical uncertainties, such as data assumptions, limitations, and quality, will also need to be transparent and carefully managed. Future life-cycle GHG indicator methodologies will benefit from collaborative efforts to harmonize key definitions, boundary conditions, allocation methods, reference data, emissions factors, and reporting consistency, particularly in cases of biogenic CO₂ emissions, waste-to-energy, and carbon reuse technologies.

References, SMEs, and Capabilities

KEYSTONE REFERENCES

AFRL, 2009, Aviation Fuel Life-Cycle Analysis Working Group, Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels, AFRL-RZ-Wp-TR-2009-2206, Air Force Research Laboratory: Wright Patterson AFB, OH, 2009, www.netl.doe.gov/energyanalyses/pubs/EstGHGFtpntsAvFuels2009.pdf.

AFRL, 2011, Life Cycle Greenhouse Gas Analysis of Advanced Jet Propulsion.

Fuels: F-T Based SPK-1 Case Study (Final Report), February 2011.

EPA, 2010, Regulatory Announcement: EPA Life-cycle Analysis of Greenhouse Gas Emissions from Renewable Fuels, EPA_420f10006, www.epa.gov/otaq/renewablefuels/420f10006.pdf.

Stratton et al., 2010, Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, Partnership for Air Transportation Noise and Emissions Reduction, Project 28, web.mit.edu/aeroastro/partner/projects/project28.html.

Wang, Michael, 2011, Overview of Life-Cycle Analysis with the GREET Model, The GREET Training Workshop, ANL, December 7-8, 2011, Systems Assessment Group, Center for Transportation Research, ANL, greet.es.anl.gov/event-workshop_dec_2011.

LIST IDENTIFIED SMES AND THEIR RESPECTIVE ORGANIZATIONS

Dr. Michael Wang, ANL, DOE

Mr. Aaron Levy, OTAQ, EPA

Mr. Timothy Skone, NETL, DOE

DESCRIBE SUPPLEMENTARY SUPPORTING CAPABILITIES

EPA National Risk Management Research Laboratory is supporting research and application of next generation LCA platforms. It is examining the use of the OpenLCA software found at: sourceforge.net/projects/openlca/.

EPA National Center for Environmental Assessment is responsible for the Triennial Report to Congress on Biofuel Impacts per requirements in EISA. Part of this assessment and analysis focuses on the life-cycle GHG aspects of the expansion of biofuels.

Resources

Allen et al., Characterizing the Greenhouse Gas Footprints of Aviation Fuels from Fischer-Tropsch Processing, www.utexas.edu/research/ceer/biofuel/pdf/UDRI_FT_GHG_Final_Report_Jan_25_2010.pdf.

ANL, GREET Series 1, Summary and Model Downloads, greet.es.anl.gov/greet_1_series.

ANL, GREET 1.0 www.transportation.anl.gov/pdfs/TA/500.pdf.

ANL, GREET 1.6 www.transportation.anl.gov/pdfs/TA/153.pdf.

ANL, GREET Workshop, December 2011, greet.es.anl.gov/event-workshop_dec_2011.

ANL, Development and Use of GREET 1.6 Fuel-Cycle Model for Transportation Fuels and Vehicle Technologies, www.transportation.anl.gov/pdfs/TA/153.pdf.

GBEP, Clearinghouse on GHG methodologies for life-cycle analysis of bioenergy, www.globalbioenergy.org/toolkit/clearing-house-on-ghg-methodologies/en/.

Brinkman, N., M. Wang, T. Weber, T. Darlington, GM Study: Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems - A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions, May 1, 2005, www.transportation.anl.gov/pdfs/TA/339.pdf.

-
- CEQ, Federal Greenhouse Gas Accounting and Reporting Guidance, October 6, 2010, www.whitehouse.gov/sites/default/files/microsites/ceq/ghg_guidance_document_0.pdf.
- CEQ, Federal Greenhouse Gas Accounting and Reporting Guidance, Technical Support Document, October 6, 2010, www.whitehouse.gov/sites/default/files/microsites/ceq/technical_support_document_1.pdf.
- Ekvall, T., and G. Finnveden. "Allocation in ISO 14041 - a critical review." *Journal of Cleaner Production* 9, no. 3 (2001): 197-208. [Ekvall_Ene-59_5050_allocation_in_iso_14041.pdf](http://www.noppa.aalto.fi/noppa/kurssi/ene-59.5050/materiaali/Ene-59_5050_allocation_in_iso_14041.pdf), https://noppa.aalto.fi/noppa/kurssi/ene-59.5050/materiaali/Ene-59_5050_allocation_in_iso_14041.pdf.
- GBEP, Task Force on GHG Methodologies, Version 1, www.globalbioenergy.org/programmeofwork/ghg/en/and www.globalbioenergy.org/programmeofwork/ghg/en/.
- Han, J., A. Elgowainy, I. Palou-Rivera, J.B. Dunn, M.Q. Wang Well-to-Wheels Analysis of Fast Pyrolysis Pathways with GREET, Nov 2011, greet.es.anl.gov/files/wtw_fast_pyrolysis.
- Intergovernmental Panel on Climate Change Special Report on Renewable Energy Sources and Climate Change Mitigation, [SRREN_FullReport.pdf](http://srren.ipcc-wg3.de/&ipcc-srren-generic-presentation-1.pdf), srren.ipcc-wg3.de/&ipcc-srren-generic-presentation-1.pdf.
- McBride, Allen C., et al. "Indicators to support environmental sustainability of bioenergy systems." *Ecological Indicators* 11 (2011), pp. 1277–1289.
- US DOE, NREL Life Cycle Inventory Web Page, www.nrel.gov/lci www.nrel.gov/lci/related_links.html.
- US EPA, Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use, EPA420-F-07-035, fact sheet, April 2007, www.epa.gov/oms/renewablefuels/420f07035.htm and cfpub.epa.gov/ols/catalog/catalog_display.cfm?&FIELD1=SUBJECT&INPUT1=Renewable%20energy%20sources%20Environmental%20aspects%20United%20States&TYPE1=EXACT&item_count=1.
- Schumann, U. "The impact of nitrogen oxides emissions from the aircraft upon the atmosphere at flight altitudes-results from the AERONox Project." *Atmospheric Environment* 31 (1997): 1723-1733. [Schumann_at-env-1723-1997.pdf](http://elib.dlr.de/32299/1/at-env-1723-1997.pdf), elib.dlr.de/32299/1/at-env-1723-1997.pdf.
- Stratton et al., 2010, Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, Partnership for Air Transportation Noise and Emissions Reduction, Project 28, web.mit.edu/aeroastro/partner/projects/project28.html.

Skone, Timothy J., and Kristin Gerdes. "Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels." US Department of Energy, National Energy Technology Laboratory, Office of Systems, Analysis and Planning. November 26, 2008. www.netl.doe.gov/energy-analyses/pubs/NETL%20LCA%20Petroleum-based%20Fuels%20Nov%202008.pdf.

US EPA, AIRCHIEF, Emission factors and AP 42, Compilation of Air Pollutant Emissions Factors, www.epa.gov/ttn/chief/ap42/.

US EPA, Code of Federal Regulation 80.1426 Approved Pathways, frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi?YEAR=current&TITLE=40&PART=80&SECTION=1426&SUBPART=&TYPE=TEXT) and www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm.

US EPA, RFS Program Website, www.epa.gov/otaq/fuels/renewablefuels/index.htm.

US EPA, LCAccess Website, www.epa.gov/NRMRL/lcaccess/lca101.html.

Wang, M., Y. Wu, and A. Elgowainy, Operating Manual for GREET: Version 1.7, ANL/ESD/05-3, Center for Transportation Research, Energy Systems Division, ANL, November 2005, Revised in February 2007, www.transportation.anl.gov/pdfs/TA/353.pdf.

WRI and the World Business Council for Sustainable Development (WBCSD), 2011, Corporate Value Chain (Scope 3) Accounting and Reporting Standard, Supplement to the GHG Protocol Corporate Accounting and Reporting Standard, GHG Protocol, www.ghgprotocol.org/standards/scope-3-standard.

Air Quality

Pillar	Environmental
Criteria	Air
Indicator	Air Quality

Air quality is the intersection of human health and energy technologies. Biomass cultivation, preprocessing, transportation, production, distribution, and use all produce air emissions, whether from fuel combustion, industrial processes, or even simple evaporation of chemicals. Unlike the differentiation in GHG between fossil (CO₂ and biogenic CO₂, biofuels air pollutant emissions come down to the absolute amount of air pollutants emitted per million British thermal unit (mmBtu) jet fuel produced and whether these pathway's activities are taking place in a jurisdiction regulated for poor air quality, such as EPA-designated non-attainment areas.

The CAA of 1990 mandates the protection and improvement of our Nation's air quality, stratospheric ozone layer, and, more recently GHGs. CAA authorizes EPA to pass regulations and support initiatives improving air quality in the United States. State and tribal governments have delegated authority to monitor air quality, issue permits, and inspect facilities within their jurisdictions. States are required to develop and update SIPs that describe how they plan to control air pollution under the CAA and include their respective state statutes and regulations. SIPs and their associated state laws and regulations determine whether a facility or operation trigger a requirement for air permit(s), annual air emission reporting, or emission controls.

EPA is responsible for setting [National Ambient Air Quality Standards](#) (NAAQS) that focuses on [six criteria air pollutants](#) harmful to human health and the environment. NAAQS pertain to the emission and acceptable limits of: carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), ozone, particulate matter (PM), and lead. Jurisdictions with pollutant levels higher than these standards are designated as nonattainment areas, which triggers greater restrictions, scrutiny, and active efforts to reduce air pollutant emissions.

Pre-processing and biofuel production facilities likely have an air permit or will require one as part of the planning, approval, and construction process. Once biofuels are delivered to the military services' installations, the emissions resulting from their distribution, use, and combustion in weapons platforms, fleets, and buildings are included in military installation air permit and considered in its maintenance and modification (the vast majority of installations and facilities maintain some type of state air permit). A proposed change or new activity that impacts criteria air pollutant emissions may trigger the requirement for new or modified facilities, Title V operating permit (100 to 250 tons per year dependent

on category), or a New Source Review Prevention of Significant Deterioration permit (250 tons per year).²⁷

The air pollutants of concern depend upon feedstock type (e.g., biomass, biogas, municipal solid waste), the technology they are used in, industrial processes, and/or even chemicals that leak into the local air shed. Certain technologies and processes emit air toxics, also known as [hazardous air pollutants](#) (HAPs). Under the CAA, Section 112, [major sources](#) of HAPs are also required to obtain operating permits and to adhere to technology-based standards, called [NESHAPs](#). Area sources are classified as activities with the potential to emit 10 tons per year of a hazardous air pollutant or 25 tons per year of a combination of different HAPs.²⁸

For the purposes of this technical sheet, we focus on air quality rather than ozone depleting substances and GHG emissions as they are addressed in separate technical sheets. However, air quality is driven by and influences numerous indicators. The input and processing energy sources chosen can greatly influence not only life-cycle GHG emissions but also a pathway's criteria air emissions. A feedstock's cultivation and preprocessing methods, such as vegetable oil solvent extraction, can likewise result in criteria pollutant and HAP emissions, which can generate more time and labor intensive regulatory compliance efforts. These compliance burden and permit delays can greatly impact availability.



RELEVANCE AND RATIONALE

Air quality was selected as an indicator because of the direct impacts on human health and the environment. Furthermore, criteria air pollutant and HAP regulations are applicable across the entire pathway life-cycle and can have substantial cost, schedule, and legal compliance consequences. Likewise, biofuel's offer advantages of lower emission rates for some pollutants and in some cases. Table B-15 highlights statutes and policies where the air quality indicator is applicable and relevant to biofuels.

²⁷ US EPA, Pacific Southwest, Region 9, Air Permits, <http://www.epa.gov/region9/air/permit/psd-public-part.html>.

²⁸ US EPA, Area Source Standards, <http://www.epa.gov/ttn/atw/area/arearules.html>.

Table B-15. Air Quality Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance
Statutory and Regulatory Relevance		
EISA of 2007		Yes
Food, Conservation, and Energy Act of 2008		Yes
National Environmental Protection Act of 1970	Yes	
CAA	Yes	
EPCRA of 1986	Yes	
USG Policy Relevance		
EO 13514	Yes	

Consideration of air quality benefits and concerns are ubiquitous, with indicators appearing in virtually every biofuel sustainability framework, approach, and industry standard (Table B-16).

Table B-16. Air Quality in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
DOE Biomass Program, Sustainability Platform	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	Yes
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	
Global Bioenergy Partnership	Yes	
ISO 14025 Product Category Rules	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

Given its presence throughout statutes, policy, and standards, the rationale for incorporating a life-cycle air quality indicator is that it is first a set of federal and state compliance requirements. Second, failing to consider life-cycle air quality metrics would pose both supply chain and military service client acceptance risks to DLA Energy.

METRICS SELECTED

Air quality metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for quantitative comparisons among drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the air pollutant emission hazards posed by a particularly pathway; and, second, identify jurisdictions with poor air quality and the resultant regulatory limitations and burden at that location.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: CO total emissions, g/mmBtu jet fuel
- ◆ Metric 2: SO_x total emissions, g/mmBtu jet fuel
- ◆ Metric 3: NO_x total emissions, g/mmBtu jet fuel
- ◆ Metric 4: PM_{2.5} total emissions, g/mmBtu jet fuel
- ◆ Metric 5: PM₁₀ total emissions, g/mmBtu jet fuel
- ◆ Metric 6: Volatile organic compounds (VOCs) total emissions, g/mmBtu jet fuel

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 7: CO non-attainment area, Yes/No
- ◆ Metric 8: SO_x non-attainment area, Yes/No
- ◆ Metric 9: NO_x non-attainment area, Yes/No
- ◆ Metric 10: PM_{2.5} non-attainment area, Yes/No
- ◆ Metric 11: PM₁₀ non-attainment area, Yes/No
- ◆ Metric 12: NESHAP/Maximum Achievable Control Technology (MACT) Standard Applicability, Yes/No

Risk Reduction (Mitigation Metric)

- ◆ Metric 13: Emission controls applied, g/mmBtu jet fuel

Air quality metrics are applicable across each step of the biofuel life cycle. One important caveat is that emission control technology in stage 5 is not likely desirable or practical for use on weapons platforms so is only minimally applicable.

Table B-17. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: CO Total Emissions	Yes	Yes	Yes	Yes	Yes
Metric 2: SO _x Total Emissions	Yes	Yes	Yes	Yes	Yes
Metric 3: NO _x Total Emissions	Yes	Yes	Yes	Yes	Yes

Table B-17. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 4: PM _{2.5} Total Emissions	Yes	Yes	Yes	Yes	Yes
Metric 5: PM ₁₀ Total Emissions	Yes	Yes	Yes	Yes	Yes
Metric 6: VOCs Total Emissions	Yes	Yes	Yes	Yes	Yes
Metric 7: CO Non-Attainment Area	Yes	Yes	Yes	Yes	Yes
Metric 8: SO _x Non-Attainment Area	Yes	Yes	Yes	Yes	Yes
Metric 9: NO _x Non-Attainment Area	Yes	Yes	Yes	Yes	Yes
Metric 10: PM _{2.5} Non-Attainment Area	Yes	Yes	Yes	Yes	Yes
Metric 11: PM ₁₀ Non-Attainment Area	Yes	Yes	Yes	Yes	Yes
Metric 12: NESHAP/MACT Standard Applicability	Minimal	Yes	Yes	Yes	Yes
Metric 13: Emission Controls Applied	Yes	Yes	Yes	Yes	Minimal

MODELING APPROACH

It is recommended that these air quality metrics be calculated using the approaches and best practices of the ISO 14040 series on LCA and incorporate air program regulatory reporting emission factors and best practices, to the full extent possible. As discussed earlier in the report, the level²⁹ of LCAs vary and the output metrics should be determined by its end use, such as generating research and development inputs (Level III), screening service-sponsored operational demonstrations (Level III and II), or evaluating specific biofuels procurements (Level II and I), particularly when examining regulatory liabilities and permitting thresholds for specific life-cycle steps.

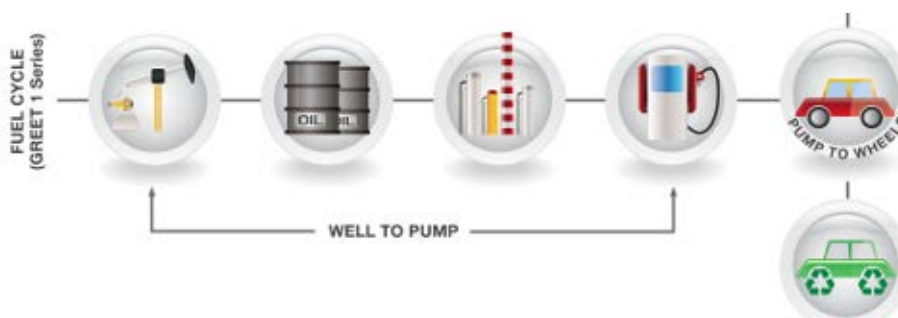
GREET1_2012

First released by ANL in 1996, GREET evaluates the energy and emissions implications of transportation fuels and vehicle technologies across their life cycle. Over the last 15 years, this attributional LCA model has been expanded into one

²⁹ There are generally three levels of LCA's: Level I: Comprehensive, Level II: Standard, and Level III: Screening. These vary in the process fidelity and data detail and serve different end uses given the level of accuracy reflected in the results.

of the leading life-cycle fuel and transportation models. GREET is compiled in a “multidimensional spreadsheet model in Microsoft Excel” and is available free of charge.³⁰ ANL plans to update this workbook version and deploy to a web-based architecture.³¹ GREET enables researchers and analysts to evaluate different fuel and vehicle combinations across fuel-cycle (stages 1–4) thru vehicle use (stage 5). Figure B-6 illustrates this scope.

Figure B-6. GREET1 2011 Fuel Cycle Scope^a



^aWang, 2011, Overview of Life-Cycle Analysis with the GREET Model, GREET Training Workshop, December 2011.

With its 2012 update, GREET has been expanded to cover over 100 pathways, including aviation fuels and several drop-in biofuel pathways, such as cellulosic pyrolysis and algae-, soybean- and camelina-oil derived HEFA jet. DLA-FAA joint work program has supported the development of this expansion with the GREET for jet effort.

GREET draws and compiles data from a broad variety of resources. In addition to DOE sources, it has incorporated authoritative emission factors and fuel product specifications. Using this compiled data, GREET’s analysis produces fuel life-cycle results for energy/fuel use, criteria air pollutants, and GHG. As such, DLA Energy engaged and worked with ANL to provide data for the relevant criteria pollutants (CO, SO_x, NO₂, PM_{2.5}, PM₁₀) and HAPs (VOCs). These air emissions calculations are in both total pollutant emissions and a subset for urban emission, that can be used as needed.³²

MEASUREMENT AND ANALYSIS APPROACH

The direct measurement and monitoring of air emissions when required by permits provides one of the most reliable means to manage these inputs and impacts. However, the time, expense, and effort needed to do so for distributed emissions sources often relies upon emission factor values, such as those found in AP-42. As GREET 1_2012 incorporates these emission factors into a life-cycle model, the following metrics use these total emission output estimates as a representative

³⁰ <http://greet.es.anl.gov/main>.

³¹ http://greet.es.anl.gov/event-workshop_dec_2011.

³² See footnote 29, this appendix.

means to estimate the air quality hazards and mitigations of biofuel production pathways. The consequences of such emissions depend upon their location and the existing air pollution burden, represented by non-attainment area designations. These metrics provide screening level information but are not a replacement for the specific analysis and process required for permitting and reporting compliance.

Metric 1–6: Total Air Pollutant Emissions (*National, Regional, or County Levels*)

Metric 1–6 directly focuses on the quantities of CO, SO_x, NO₂, PM_{2.5}, PM₁₀, and VOCs produced and emitted to the local air shed across the entire fuel life-cycle (stages 1–5). Total emissions estimated in units of g/mmBtu jet fuel biofuel using the low heating value by each life-cycle stage and in total for the pathway. This metric is greatly influenced by the cultivation system, fuels combusted, industrial processes and chemicals used, and the biofuels ultimate end use, such as in jet turbine, diesel engine, etc.

As the direct measure criteria pollutant and HAP emissions is technically involved and highly costly, these metrics are generated from the modeled feedstock and fuel pathways generated by the GREET 1_2012 model. The DLA Energy output template add-on compiles this information and is directly used to calculate the metrics and their hazard ratings.

Key measurements, databases, and approaches for calculating Metric 1–6 include:

- ◆ GREET 1_2012, DLA Energy Output Results Sheet, 2005 Petroleum Jet
- ◆ GREET 1_2012, DLA Energy Output Results Sheet, Soybean HEFA Jet
- ◆ GREET 1_2012, DLA Energy Output Results Sheet, Camelina HEFA Jet

The analysis thresholds for these total air pollutant emission metrics are based on the 2005 petroleum jet fuel baseline from GREET. The threshold level breaks are calculated using standard “Gaussian” or “normal” distributions as presented in Table B-18.

Table B-18. Total Emission Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	≤ STD -2 of 2005 Petroleum Jet Total Emissions
Low	2	≤ STD -1 of 2005 Petroleum Jet Total Emissions
Moderate	3	≤ 2005 Petroleum Jet Total Emissions
High	4	≤ STD 1 of 2005 Petroleum Jet Total Emissions
Highest	5	> STD 1 of 2005 Petroleum Jet Total Emissions

Note: STD = standard deviation

These threshold levels should be reassessed and analyzed with every new update to GREET and its petroleum baseline.

Metrics 7–11: Non-Attainment Areas (*Region or County Levels*)

As a consequence component, Metrics 7–11 focus on whether the local county or region has been designated as in non-attainment for the subject criteria pollutants. This indicates that this local air shed exceeds air pollutant levels per NAAQS and endangers human health. If a county is in non-attainment, this is indicative of sensitivity to further air pollution and likely indicative of a higher level of regulatory scrutiny and compliance burden.

Key measurements, databases, and tools for calculating Metrics 7–11 include:

- ◆ EPA, Green Book, Non-attainment Status for Each County by Year (http://www.epa.gov/airquality/greenbk/anay_ak.html).

Once a pathway's location(s) is identified, EPA's Green Book Non-attainment Status portal should be used to identify whether the county is listed as in non-attainment for the air pollutant of interest. Apply these findings against the thresholds presented in Table B-19 to determine the resultant consequence of this pollutant hazard.

Table B-19. Non-Attainment Area Thresholds

Consequence of hazard	Assessed value	Threshold
Moderate	3	County is not designated as in non-attainment
High	4	County is rural and designated as in non-attainment
Highest	5	County is urban and designated as in non-attainment

Metric 12: NESHAP/MACT Standards Applicability

Metric 12 is the consequence metric for VOCs and other HAPs of interest. This metric focuses on whether one or more activities across a pathway are source categories covered by a NESHAP. The identified activity involves the use and release of HAPs that exceed air toxic standards and endanger human health. One or more covered source category activities covered by NESHAPs would represent a higher level of regulatory scrutiny and compliance burden.

Key measurements, databases, and tools for calculating Metric 12 include:

- ◆ EPA, Technology Transfer Network Air Toxics Website, National Emission Standards for Hazardous Air Pollutants (<http://www.epa.gov/ttn/atw/mactfnlalph.html>)
- ◆ EPA, Technology Transfer Network Air Toxics Website, Area Source Standards (<http://www.epa.gov/ttn/atw/area/arearules.html>).

Once a pathway and its activities are identified, EPA’s Technology Transfer Network Air Toxics Website on NESHAP should be used to identify whether a NESHAP applies to relevant activities, such as refinery operations and solvent extraction of vegetable oil. Apply these findings against the thresholds presented in Table B-20 to determine the resultant consequence of this pollutant hazard.

Table B-20. NESHAP/MACT Standards Applicability Thresholds

Likelihood of hazard	Assessed value	Threshold
Low	2	NESHAP/MACT standards are not applicable
Moderate	3	NESHAP/MACT standards are applicable to one pathway activity
High	4	NESHAP/MACT standards are applicable to two pathway activities
Highest	5	NESHAP/MACT standards are applicable to three or more pathway activities

Metric 13: Emission Controls Applied

Metric 13 addresses the air quality mitigation measures that can be used to reduce risks associated with biofuel production pathways. The key question is whether emissions controls can be applied and their effectiveness on reducing total emissions.

Key measurements, databases, and tools for calculating Metric 13 include:

- ◆ Direct monitoring, and compliance data provided by preprocessing or bio-refinery producers
- ◆ EPA, Technology Transfer Network, Clearinghouse for Inventories and Emissions Factors, Emissions Factors and AP 42, Compilation of Air Pollutant Emission Factors (<http://www.epa.gov/ttnchie1/ap42/>).

If emission controls are applied to emission sources, Metrics 1–6 should be recalculated to estimate the new total pollutant emissions. This revised estimate would be reassessed against the thresholds in Table B-18 to determine the mitigated hazard ratings. The reassessed rating may then reduce the raw risk number due to a lower likelihood hazard and resultant impact to local air quality.

General Considerations, Assumptions, and Uncertainties

LCA is guided by ISO 14040 series and best practices, but there can be significant differences in the emission factors used and control technologies assumed, which can lead to uncertainty and questions of acceptability for state specific regulatory impact estimates. Likewise, system level uncertainties, such as differing inventory boundaries or co-product allocation methods, can make LCA’s difficult to

compare. For new and emerging pathways, technical uncertainties, such as data assumptions, limitations, and quality, will also need to be transparent and carefully managed. Future life-cycle air quality indicator methodologies will benefit from collaborative efforts to harmonize key definitions, boundary conditions, allocation methods, reference data, emissions factors, and reporting consistency.

RESOURCES, SMES, AND CAPABILITIES

Keystone Resources

Air Pollution Training Institute (APTI) Learning Management System (APTI-Learn), review.em-assist.com/LMS/EPA/login.aspx?ReturnUrl=%2fflms%2fepa%2fdefault.aspx

AFRL, 2009, Aviation Fuel Life-Cycle Analysis Working Group, Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels, AFRL-RZ-Wp-TR-2009-2206, AFRL: Wright Patterson AFB, OH, 2009, www.netl.doe.gov/energyanalyses/pubs/EstGHGFtpntsAvFuels2009.pdf

AFRL, 2011, Life-Cycle Greenhouse Gas Analysis of Advanced Jet Propulsion

EPA, Green Book, Nonattainment Status for Each County by Year, www.epa.gov/airquality/greenbk/anay_ak.html

EPA, Technology Transfer Network Air Toxics Website, NESHAPs, www.epa.gov/ttn/atw/mactfnlalph.html

EPA, Technology Transfer Network Air Toxics Website, Area Source Standards, www.epa.gov/ttn/atw/area/arearules.html

EPA, Technology Transfer Network, Clearinghouse for Inventories and Emissions Factors, Emissions Factors and AP 42, Compilation of Air Pollutant Emission Factors, www.epa.gov/ttnchie1/ap42/

Wang, Michael, 2011, Overview of Life-Cycle Analysis with the GREET Model, The GREET Training Workshop, ANL, December 7-8, 2011, Systems Assessment Group, Center for Transportation Research, ANL, greet.es.anl.gov/event-workshop_dec_2011

Identified SMEs and Organizations

Dr. Michael Wang, ANL, DOE

Mr. Aaron Levy, OTAQ, EPA

Mr. Timothy Skone, NETL, DOE

Supplementary Supporting Capabilities

EPA National Center for Environmental Assessment is responsible for the Triennial Report to Congress on Biofuel Impacts per requirements in EISA. Part of this assessment and analysis focuses on the life-cycle air quality aspects of the expansion of biofuels.

REFERENCES

- ANL, GREET Series 1, Summary and Model Downloads, greet.es.anl.gov/greet_1_series.
- ANL, GREET Workshop, December 2011, greet.es.anl.gov/event-workshop_dec_2011.
- ANL, Development and Use of GREET 1.6 Fuel-Cycle Model for Transportation Fuels and Vehicle Technologies, www.transportation.anl.gov/pdfs/TA/153.pdf.
- GBEP, Clearinghouse on GHG methodologies for life-cycle analysis of bioenergy, www.globalbioenergy.org/toolkit/clearing-house-on-ghg-methodologies/en/.
- Brinkman, N., M. Wang, T. Weber, T. Darlington, GM Study: Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems - A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions, May 1, 2005, www.transportation.anl.gov/pdfs/TA/339.pdf.
- Ekvall, T., and G. Finnvedeen. "Allocation in ISO 14041 - a critical review." *Journal of Cleaner Production* 9, No. 3 (2001): 197–208. [Ekvall_Ene-59_5050_allocation_in_iso_14041.pdf](http://www.noppa.aalto.fi/noppa/kurssi/ene-59.5050/materiaali/Ene-59_5050_allocation_in_iso_14041.pdf), https://noppa.aalto.fi/noppa/kurssi/ene-59.5050/materiaali/Ene-59_5050_allocation_in_iso_14041.pdf.
- GBEP, Task Force on GHG Methodologies, Version 1, www.globalbioenergy.org/programmeofwork/ghg/en/ and www.globalbioenergy.org/programmeofwork/ghg/en/.
- Han, J., A. Elgowainy, I. Palou-Rivera, J.B. Dunn, M.Q. Wang Well-to-Wheels Analysis of Fast Pyrolysis Pathways with GREET, Nov 2011, greet.es.anl.gov/files/wtw_fast_pyrolysis.
- McBride, Allen C., et al. "Indicators to support environmental sustainability of bioenergy systems." *Ecological Indicators* 11 (2011), pp. 1277–1289.
- US DOE, National Renewable Energy Laboratory Life-Cycle Inventory Web Page, www.nrel.gov/lci and www.nrel.gov/lci/related_links.html.

- Schumann, U. "The impact of nitrogen oxides emissions from the aircraft upon the atmosphere at flight altitudes-results from the AERONox Project." *Atmospheric Environment* 31 (1997), 1723–1733, Schumann_at-env-1723-1997.pdf, elib.dlr.de/32299/1/at-env-1723-1997.pdf.
- Stratton et al., 2010, Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, Partnership for Air Transportation Noise and Emissions Reduction, Project 28, web.mit.edu/aeroastro/partner/projects/project28.html.
- Skone, Timothy J., and Kristin Gerdes. "Development of Baseline Data and Analysis of Life-Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels." US DOE, National Energy Technology Laboratory, Office of Systems, Analysis and Planning, November 26, 2008, www.netl.doe.gov/energy-analyses/pubs/NETL%20LCA%20Petroleum-based%20Fuels%20Nov%202008.pdf.
- US EPA, AIRCHIEF, Emission factors and AP 42, Compilation of Air Pollutant Emissions Factors, www.epa.gov/ttn/chief/ap42/.
- US EPA, Renewable Fuel Standard Program Website, www.epa.gov/otaq/fuels/renewablefuels/index.htm.
- US EPA, LCAccess Website, www.epa.gov/NRMRL/lcaccess/lca101.html.
- Wang, M., Y. Wu, and A. Elgowainy, Operating Manual for GREET: Version 1.7, ANL/ESD/05-3, Center for Transportation Research, Energy Systems Division, ANL, November 2005, Revised in February 2007, www.transportation.anl.gov/pdfs/TA/353.pdf.

Stratospheric Ozone Depletion

Pillar	Environmental
Criteria	Air
Indicator	Ozone Depletion

Depletion of the stratospheric ozone layer is perhaps one of the most well known environmental issues in recent history. The Antarctic “ozone hole” and its inability to block harmful ultraviolet radiation onto the Earth’s surface became the iconic manifestation of this global environmental issue and ultimately resulted in the Montreal Protocol treaty, which was ratified by the US Senate in 1988. Stratospheric ozone depletion was scientifically linked to emission of several families of synthetic industrial chemicals designated as ODS. The impact of each ODS on a mass basis is quantified using an ozone depletion potential (ODP). In addition, ODS often have high GWPs.

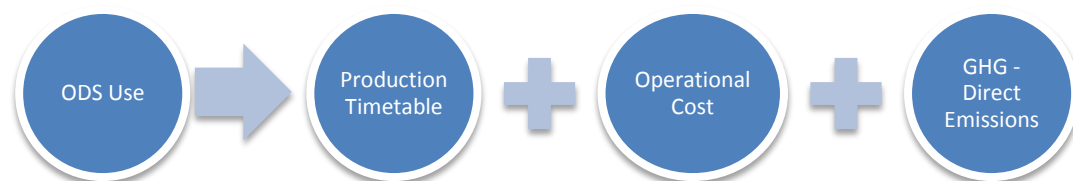
ODSs include a number of chemical compounds containing chlorine or bromine that can be used in fire suppression systems, refrigeration and cooling systems, as solvents, and fumigants. Perhaps one of the most well known ODS families are the chlorofluorocarbons (CFCs) or “Freon”. There are several classes of chemicals identified and targeted for ban or phase out under the [Montreal Protocol](#) and [Title VI](#) of the US CAA mandate. Title 40 Code of Federal Regulations, Part 82 established implementing regulations, as administered by EPA. Class I ODS are classified as chemicals with ODPs greater than 0.2 and were largely banned for production by the [end of the 1990s](#), though there are some [limited exemptions](#) for their continued use. Class I ODS³³ include chemicals such as: CFCs, Halons, Carbon Tetrachloride, Methyl Chloroform, [Methyl Bromide](#), and hydrobromofluorocarbons (HBFCs).

Class II ODS³⁴ are classified as substance with ODPs less than 0.2 and include hydrochlorofluorocarbons (HCFCs), which are widely used in refrigerants and foam blowing agents. Class II substances are currently being phased out of production and [use through 2030](#). For example, commonly used refrigerant R-22/HCFC-22 was already phased out of production in 2010 for new equipment.

³³ For full listing of Class I ODS chemicals, refer to: <http://www.epa.gov/ozone/science/ods/classone.html>.

³⁴ For full listing of Class II ODS chemicals, refer to: <http://www.epa.gov/ozone/science/ods/classtwo.html>.

The ozone depletion indicator is not impacted greatly by other criteria or indicators, but ODS inputs, consumption, and releases could have downstream impacts.



Linkages to production timetable and cost are largely associated with the material obsolescence risks inherent with using legacy equipment that rely on an increasingly scarce, expensive, and regulated input. Inadvertent dependence on feedstock processing or production technologies that require ODS may prove to be an unexpected limitation during scale up efforts. In addition, ODS also tend to be powerful GHGs and could impact GHG direct emissions, even though they are often only subject to voluntary reporting schemes.

RELEVANCE AND RATIONALE

Ozone depletion was selected as an indicator because of the direct environmental impacts that ODS emissions might pose, and more so, to elevate the awareness of supply chain material obsolescence issues, particularly with the Class II substances that are beginning to be phased out over the next two decades. While new facilities and infrastructure would not likely utilize ODS, awareness is warranted so legacy feedstock cultivation practices, transportation systems, and production equipment designs that use ODS are not scaled up, resulting in inadvertent compliance, material availability, and cost issues. Table B-21 highlights statutes and policies where the ODS indicator is most relevant.

Table B-21. US Statutes and Policies Relevant to Ozone Depletion

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
EISA of 2007		Yes	
CAA		Yes	
USG Policy Relevance			
EO 13423	Yes		
EO 13514	Yes		
DoD and Service Policy Relevance			
DoD Instruction 4715.4	Yes		

Ozone depletion indicators are found in a limited number of bioenergy frameworks and approaches (Table B-22). While not ubiquitous, DLA chose to retain this indicator as it does represent a known environmental compliance item and

could have material obsolescence implications, such as availability and cost, when scaled up.

Table B-22. Ozone Depletion in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
ORNL, Center for BioEnergy Sustainability	Yes	Yes
CAAFI Environmental Working Group	Yes	
ISO 14025 Product Category Rules	Yes	

METRICS SELECTED

Life-cycle ODS emission metrics have been identified and selected to: 1) determine ODS applicability; and 2) extent of feedstock processing and conversion pathway dependence.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Total Class I ODS Emissions
 - If yes, then, the metric being tracked would be grams (g) ODS emitted/mmBTU biofuel
- ◆ Metric 2: Total Class II ODS Emissions
 - If yes, then, the metric being tracked would be grams (g) ODS emitted/mmBTU biofuel

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Not applicable—global scope of impact

Risk Reduction (Mitigation Metrics)

- ◆ Metric 3: Availability of substitute material or technology, Yes/No

ODS applicability has been evaluated for each biofuel lifecycle step and are shown below (Table B-23).

Table B-23. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Total Class I ODS Emitted	Yes	Minimal	Minimal	Minimal	N/A
Metric 2: Total Class II ODS Emitted	Minimal	Minimal	Yes	Yes	N/A
Metric 3: Substitute available	Yes	Yes	Yes	Yes	N/A

Note: Stage # 2 may have incidental releases of ODS from older vehicle A/C units, but, as this is not an integral function, it is not considered to be a supply chain risk. Likewise, Stage # 4 use of Class I ODS are less likely as their growing scarcity since 2000 has dramatically increased scarcity and price, which has driven industrial and commercial uses to Class II ODS or alternatives, such as HFC compounds.

MEASUREMENT AND ANALYSIS APPROACH

Inherent in Metrics 1 and 2 is the need to first identify whether a Class I or II ODS is being used and then quantify the estimated emissions across the applicable biofuel life cycles (stages 1–4). There are two potential applications of consequence to identify are: 1) use of methyl bromide in stage 1 feedstock processing as fumigant; and 2) CFC and HCFC refrigerants use in stages 3 and 4. Mobile vehicle air conditioning is a potential source in stage 1, 2, & 4, but these uses are for employee comfort rather than a process integral use. As such, they are potential sources to note but not a supply chain risk per se. In addition, such application may fall under the EPA 50-pound recordkeeping threshold per 40 CFR 82.166 (j) and (k).³⁵

Metric 1: Total Class I ODS Emissions

Metric 1 should be approached in three steps of: 1) determining applicability (i.e., use of Class I ODSs); 2) determining the estimate emissions from the identified applicable process or equipment; and 3) normalizing the emission by the fuel production.

Key data sources for calculating Metric 1 will reside with the feedstock cultivator, transporter, biofuel producer, and biofuel distributor. As centralized databases do not exist for this application, this metric would first require a process or equipment applicability screening to determine whether a Class I ODS would even be potentially used in such a supply chain. For instance, review of the feedstock producer crops and processes can be compared to the existing EPA lists of soil and structural fumigant uses covered by the [Critical Use Exemption](#) (CUE). Likewise,

³⁵ More information on ODS reporting regulations, and the 50-pound reporting requirement can be found at: <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=40:17.0.1.1.2&idno=40#40:17.0.1.1.2.6.1.10>.

identifying the need for process and equipment cooling can help narrow the potential uses of Class I ODS.

Second, if there is potential applicability or use, the next step would be to request existing Title VI recordkeeping (ODS purchases and returns to supply system) and the annual biofuel output from the biofuel producer. Finally, a simple screening approach³⁶ (quantity ODSs purchased or issued to workers minus quantities returned to supply system) can be calculated to estimate total ODS releases. Total quantity estimates should retain sufficient data granularity for identification of the specific ODS, application, or equipment.

Table B-24. Total Class I ODS Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	No Class I ODS application present
Low	2	Class I ODS application confirmed in critical process(es) but under 50-pound recordkeeping requirement
Moderate	3	Class I ODS application confirmed in critical process(es) and over 50-pound recordkeeping requirement
High	4	Class I ODS application confirmed in critical process(es), subject to EPA regulatory exemption, and less than 500 kilograms emitted per year
Highest	5	Class I ODS application confirmed in critical process(es), subject to EPA regulatory exemption, and more than 500 kilograms emitted per year

Metric 2: Total Class II ODS Emissions

Metric 2 should be approached in a similar manner to that elaborated in Metric 1. Follow the same three steps of: 1) determining applicability (i.e., use of Class II ODSs); 2) determining the estimate emissions from the identified applicable process or equipment; and 3) normalizing the emission by with the allocated annual fuel production.

Key data sources for evaluating and calculating Metric 2 will also reside with the feedstock cultivator, transporter, biofuel producer, and biofuel distributor. On-site or contracted heating ventilation and air conditioning technician will be able to provide recharge and recovery quantities when servicing applicable cooling systems.

³⁶ More information on the screening methodology and advanced fugitive emission estimation approaches are available in the CEQ, Federal Greenhouse Gas Accounting and Reporting Guidance, Technical Support Document, which can be found at: http://www.whitehouse.gov/sites/default/files/microsites/ceq/technical_support_document_1.pdf.

Table B-25. Total Class II ODS Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	No Class II ODS application present
Low	2	Class II ODS application confirmed in critical process but under 50-pound recordkeeping requirement
Moderate	3	Class II ODS application confirmed in critical process(es) and over 50-pound recordkeeping requirement
High	4	Class II ODS application confirmed in critical process(es) that emit less than 1000 kilograms per year
Highest	5	Class II ODS application confirmed in confirmed in critical process(es) that emit more than 1000 kilograms per year

Metric 3: Availability of Substitutes

Metric 3 reflects the availability of materials and/or technologies that can be substituted in the critical process(es) as identified in Metric 1 or 2. This measures focus is on mitigating the ozone depletion supply chain risk with alternatives. Since the passage of the Montreal Protocol and the CAA Amendments of 1990, industry, EPA, and the DoD have all been developing effective ODS alternatives, but a limited number of substitutes represent both cost, effectiveness, and technical challenges (Table B-26).

Table B-26. Alternative Availability Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Readily available drop-in alternative material or technology.
Low	2	N/A
Moderate	3	Alternative is available but is costly and/or less effective.
High	4	N/A
Highest	5	No alternative for the particular application.

General Considerations, Assumptions, and Uncertainties

Approaches and technologies that utilize ODS are well documented and managed as a mature environmental issue. However, the need for and use of ODS in new feedstock processing and biofuel production is an area of uncertainty that still requires due diligence.³⁷ This indicator's metrics were developed to identify applications and, then, pursue data on total ODS emissions. While quantities over 50

³⁷ Emerging science is also suggesting that N₂O emissions may have ozone depleting impacts. N₂O is not considered a Montreal Protocol ODS and included under life-cycle GHG indicator. While not currently considered an ODS, new scientific findings should be monitored as definitive findings might spur its addition to a ODS list in the future.

pounds are subject to recordkeeping and pose the greater supply chain risk, smaller quantities of ODS used in a decentralized manner can represent a risk but involve uncertainty and limited data, particularly with Class II ODS just now starting to be phased out. That said, the experience gained throughout the federal sector with fugitive screening processes and the best practices documented in the CEQ, Federal GHG Accounting and Reporting TSD can help minimize this uncertainty. Likewise, as greater experience is gained with feedstock processing and advanced biofuel production is gained, future applicability screening methods should be refined to best incorporate the assessment surprises encountered and build on proven methods to manage this sustainable supply chain risk.

RESOURCES, SMEs, AND CAPABILITIES

Resources

US EPA, 2009, The U.S. Phaseout of HCFCs: Projected Service Needs in the U.S. Air-conditioning and Refrigeration Sector, Final Report

US EPA, 2010, Ozone Layer Protection - Regulatory Programs Web Page, <http://www.epa.gov/ozone/title6/index.html>

US EPA, 2011, Significant New Alternatives Policy (SNAP) Program Web Page, <http://www.epa.gov/ozone/snap/>

NASA, 2011, Regulatory Risk Analysis and Communication (RRAC) Web Page, <http://www.nasa.gov/offices/emd/home/regcom.html>

United Nations Environmental Program, Ozone Secretariat Web Page, http://ozone.unep.org/Publications/MP_Handbook/Section_1.2_Control_measures/

Identified SMEs and Organizations

Mr. David Asiello, OSD, DoD

Mr. David Amidei, Environmental Management Division, NASA

Mr. Sam Higuchi, Environmental Management Division, NASA

Dr. Linda Wennerberg, Environmental Management Division, NASA

Supplementary Supporting Capabilities

Currently, the FEMP GHG and Sustainability Report contains a mixed refrigerant calculator that can accept quantities of mixed refrigerants and generate the equivalent quantities of HFCs compounds. The US Army's Air Program Manager supported initial work to expand this calculator to likewise include Class I and II

ODS. If approaches or processes are found to potentially involve ODS, this simple MS Excel calculator may be leveraged to aid with screening analysis of raw mixed refrigerant data provided by biofuel producers.

REFERENCES

DoD, ESOH in Acquisition, <https://www.denix.osd.mil/esohacq/>

DoD, 1998, DoD Instruction 4715.4, Emerging Contaminants,
<http://www.dtic.mil/whs/directives/corres/pdf/471504p.pdf>

DoD, 2009, DoD Instruction 4715.18, Emerging Contaminants,
<http://www.dtic.mil/whs/directives/corres/pdf/471518p.pdf>

CEQ, Federal Greenhouse Gas Accounting and Reporting Guidance, TSD,
http://www.whitehouse.gov/sites/default/files/microsites/ceq/technical_support_document_1.pdf

WATER QUANTITY

Pillar	Environmental
Criteria	Water
Indicator	Water Quantity

Water quantity, also known as the water footprint, is the amount of water used for a specific purpose. In this case, water quantity is defined as the amount of water required to produce drop-in biofuels. The amount of water used is often quantified in one of two ways: water withdrawal or water consumption. The US Geological Survey (USGS) defines these terms as follows:

- ◆ *Withdrawal.* Water removed from the ground or diverted from a surface-water source for use.
- ◆ *Consumptive use.* The part of water withdrawal that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.³⁸

Within the context of biofuels, water quantity refers to the aggregate total amount of water used across its life cycle, but the primary focus is feedstock production and biofuel production for this indicator. Water used for feedstock transportation, biofuel transportation, and biofuel use is generally negligible.

The water quantity indicator is most applicable at watershed, regional, and local levels. It is related to and influences other indicators, such as GHG emissions, productive capacity of land, soil quality, and water quality.³⁹



For example, McBride et al has suggested that a decrease in both infiltration and water holding capacity in soil can result in greater peak storm flows, which, in turn, can cause increased erosion and sediment loading.”⁴⁰ However, for purposes of DLA Energy’s sustainability assessment approach, we differentiate water

³⁸ USGS, “Estimated Use of Water in the United States in 2005,” Circular 1344, 2009.

³⁹ GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

⁴⁰ McBride, Allen C., et al., “Indicators to support environmental sustainability of bioenergy systems,” *Ecological Indicators* 11 (2011), p. 1281.

quantity from water quality indicators for enhanced transparency and conformance with biofuel sustainability frameworks.⁴¹

Relevance and Rationale

Despite limited mention in federal law, water quantity as a topic and indicator is predominantly mentioned in recent US biofuel statutes, relevant USG policies, and DoD plans. In addition, the vast majority of biofuel sustainability frameworks and standards likewise focus on this key resource and its use.

Table B-27. Water Quantity Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
Biomass Research and Development Act of 2000		Yes	
2002 Farm Bill	Yes		
Energy Policy Act of 2005	Yes		
EISA of 2007		Yes	
Food, Conservation, and Energy Act of 2008		Yes	
National Environmental Protection Act of 1970	Yes		
USG Policy Relevance			
EO 13423	Yes		
EO 13514	Yes		
Office Management and Budget Scorecard	Yes		
DoD and Service Policy Relevance			
DoD Strategic Sustainability Performance Plan FY10	Yes		
DoD Strategic Sustainability Performance Plan FY11	Yes		
Army Sustainability Report 2010	Yes		

Interest in the quantity of water withdrawn and consumed is widespread, with indicators appearing in virtually every biofuel sustainability framework, approach, and industry standard (Table B-28).

⁴¹ “Water consumption may be categorized further as green water (rain water), blue water (ground or surface water used for irrigation), or gray water (water contaminated during production) sources” (AEPI, *Quantifying the Army Supply Chain Water Footprint*). The withdrawal and consumption metrics principally address blue water use, as these metrics primarily measure surface and groundwater withdrawal and consumption amounts.

Table B-28. Water Quantity in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
DOE Biomass Program, Sustainability Platform	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	Yes
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	Yes
GBEP	Yes	Yes
Council on Sustainable Biomass Production	Yes	

Metrics Selected

Water quantity has been identified and selected as one of the key environmental sustainability indicators of biofuel sustainability. “Access to sufficient water supplies is critical to ensuring long-term capacity of bioenergy feedstock production and processing.”⁴² As bioenergy feedstock growth and processing may require large amounts of water in a given local area or region, some pathways have the potential to impact water availability for other uses, water quality, and even operational costs.⁴³ In short, it is a critical natural resource and even a subject of national security. As such, the following metrics have been selected for DLA Energy use.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Water Withdrawal Requirements
 - Water Withdrawal for Feedstock Generation, gal water/bushel
 - Water Withdrawal for Biofuel Processing, gal water/gal biofuel
- ◆ Metric 2: Water Consumption
 - Water Consumption for Feedstock Generation, gal water/bushel
 - Water Consumption for Biofuel Processing, gal water/gal biofuel.

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 3: Water Stress Level, % of total annual water withdrawals (TAWW) in relation to total actual renewable water resources (TARWR) (*national level screening only*)
 - TAWW: Total Annual Water Withdrawals

⁴² See footnote 39, this appendix, p. 57 (GBEP).

⁴³ See footnote 39, this appendix, p. 57 (GBEP).

- TARWR: Total Actual Renewable Water Resources
- ◆ Metric 4: Water Withdrawal Change, percent
- ◆ Metric 5: Streamflow/Discharge, ft³/s
- ◆ Metric 6: Peak Storm Flow, ft³/s.

Risk Reduction (Mitigation Metrics)

- ◆ Metric 7: Water Management Plan in Place? (Yes/No).

Water quantity metrics are most relevant to the feedstock cultivation and biofuel production stages of the fuel production life cycle (Table B-29). As noted by GBEP, “in most cases, the vast majority of water used for bioenergy (or fossil fuel) production will be used in the feedstock production (extraction) and processing (refining) phases.”^{44,45}

Table B-29. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Water Withdrawal Requirements	Yes	Minimal	Yes	Minimal	Minimal
Metric 2: Water Consumption	Yes	Minimal	Yes	Minimal	Minimal
Metric 3: Water Stress Level	Yes	Minimal	Yes	Minimal	Minimal
Metric 4: Water Withdrawal Changes	Yes	Minimal	Yes	Minimal	Minimal
Metric 5: Streamflow/Discharge	Yes	Minimal	Yes	Minimal	Minimal
Metric 6: Peak Storm Flow	Yes	Minimal	Yes	Minimal	Minimal
Metric 7: Water Management Plan	Yes	Minimal	Yes	Minimal	Minimal

Measurement and Analysis Approach

Calculating the selected metrics requires several data sources for inputs as well as to define the later analysis thresholds. In addition, it should be noted that some metrics and data sources enable the user to screen water quantity vulnerability at

⁴⁴ See footnote 39, this appendix, p. 63 (GBEP).

⁴⁵ However, if a particular biofuel production pathway involves water-intensive transportation methods, water use for transportation should be factored into overall water quantity calculations. See footnote 39, this appendix, p. 63 (GBEP).

the national level, while others can reflect water quantity characteristics, sensitivity, and mitigation at the regional, county, or even producer levels. Using these data sources, metrics can be analyzed using established thresholds for assessing water quantity sustainability at these different levels.

Many biofuel *Pathway Characteristics* are already measured, collected, and/or disseminated through existing literature and databases. Other producer or facility specific water withdrawal and water consumption factors require measurement or engineering estimates supplied by feedstock producers and biorefiners, respectively. Likewise, *Regional or Site Assessment Sensitivity* measures are available databases and sources maintained by USGS, state water authorities, or may require measurement.

Where data are available, the metric thresholds are needed to analyze water quantity sustainability within a given scale. These thresholds should not be considered static as they can be crop-, technology-, or region-specific. The following sections detail approach, data, and analysis methods needed to generate the sustainability assessment results.

METRIC 1: WATER WITHDRAWAL REQUIREMENTS (*PATHWAY OR PRODUCER LEVELS*)

Metric 1 reflects the quantity of water that is diverted from surface waters or removed from aquifers during the biofuels life cycle. It is primarily related to feedstock cultivation and biofuel processing life-cycle stages. As such, it is highly dependent upon the crop grown, cropping system used, biofuel processing technology in place, and, in some cases, biorefinery location.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ ANL biofuel pathway water quantity screening tool (*in development*)
- ◆ Water Footprint Network (www.waterfootprint.org/?page=files/WaterStat-ProductWaterFootprints)⁴⁶
 - Provides dataset of overall 1996–2005 water consumption estimates for crops used to produce ethanol and biodiesel (www.waterfootprint.org/downloads/Report47-Appendix-III.zip)
 - Dataset provides US specific blue, green, and grey water footprint information by country and state
 - “Green,” “blue,” and “grey” watercrops estimates and derived crop products (www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf)

⁴⁶ These documents provide estimates of water consumption. Water withdrawal amounts will be at least as much, and in most cases greater, than water consumption amounts.

◆ Producer measurements or engineering estimates.

ANL is currently developing a feedstock and conversion pathway screening tool to model water quantity across the biofuel life cycle. This capability can be useful for planning for and estimating water withdrawal and water consumption for various biofuel production pathways. While this model will serve purpose for initial pathway screening, it will not substitute for the more detailed Level II or I LCA estimates and measurements. As water withdrawal requirements have implications at the local and regional level, producers data or estimate may be available as part of the investor due diligence packages or later from operational records.

Water withdrawal for feedstock generation can be assessed or, where feasible, even monitored at the site of crop production (irrigation/acre). Water withdrawal (gallons) and feedstock production rates (bushels, tons, etc./acre) data can be used to create average water withdrawal factors (gallons/bushel, gallons per ton, etc.).

Likewise, the water withdrawal required for biofuel production at the biorefinery is another significant life-cycle stage. “Total water withdrawal is typically metered and can be reported by biorefinery managers.”⁴⁷ Biofuel output from the refinery can be captured and used to determine the average gallons of water withdrawn/gallon of biofuel produced.

Once both factors are calculated, the user can calculate the total amount of water withdrawn per gallon of biofuel for feedstock acquisition and biofuel production:

1. Water Withdrawal for Feedstock Acquisition (W_{FA}):

$$\frac{\text{Gallons Water}}{\text{Bushel of Feedstock}} \times \frac{\text{Bushels of Feedstock}}{\text{Gallon Biofuel}} = \frac{\text{Gallons Water}}{\text{Gallon Biofuel}}$$

2. Water Withdrawal for Biofuel Production (W_{BP}) =

$$\frac{\text{Gallons Water for Biorefining}}{\text{Gallon of Biofuel Produced in Biorefinery}}$$

3. Total Water Withdrawal = $W_{FA} + W_{BP}$

Once these rates are calculated, it is necessary to put them into context through the use of analysis thresholds. Table B-30 presents default thresholds for gallons

⁴⁷ See footnote 40, this appendix, (McBride).

of water withdrawn/gallon of biofuel produced. These thresholds are generated by comparing the baseline rates estimated for the production of petroleum fuels.⁴⁸

Table B-30. Water Withdrawal Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Water-Positive (Returned > Withdrawal)
Low	2	Net-zero: Returned = Withdrawal
Moderate	3	Greater than Net-zero but less than 12.9 gal/gal biofuel
High	4	Greater than or equal to 12.9 gal/gal biofuel but less than 25.8 gal/gal biofuel
Highest	5	Greater than or equal to 25.8 gal/gal biofuel

METRIC 2: WATER CONSUMPTION (PATHWAY OR PRODUCER LEVELS)

The key difference between water withdrawal (Metric 1) and consumption (Metric 2) is that the former borrows (and returns) liquid water from the direct environment while the latter effectively removes it (returns it to atmosphere or incorporates it into products). In other words, consumption is a subset of withdrawal, relating to that portion of water displaced and unavailable for local reuse.

Key measurements, models, and tools for calculating Metric 2 include:

- ◆ ANL high-level water quantity screening tool (*in development*)
- ◆ Water Footprint Network (see resources cited in Metric 1 above)
- ◆ Producer measurements or engineering estimates.

Water consumption for feedstock cultivation and biofuel production is highly dependent upon the feedstock and technology used. Producer measurements or mass balance engineering estimates on water consumption should be sought for feedstock cultivation and feedstock production, to the greatest extent feasible. While these data may be challenging to obtain, their use to calculate consumption values is performed by subtracting the amount of water returned to the watershed from the total water withdrawn. Using similar calculations as in Metric 1, water consumption can then be converted into units of gallons of water consumed per gallon of biofuel or gallons of water per unit of energy (e.g., MJ). This will provide an estimate of how much of the water withdrawn is effectively removed from the geographic unit (county, watershed, etc.) under study.

⁴⁸ Per King and Webber article “The Water Intensity of the Plugged-In Automotive Economy” (2008) [with values based primarily on Gleick (1994)], water withdrawal for mining and refining oil into gasoline is estimated at 12.9 gallons of water per gallon of gasoline (p. 4310). Calculations also displayed in supporting documentation to King and Webber article “Water Intensity of Transportation.” This is used as the basis for the withdrawal thresholds for biofuel production.

As with water withdrawal rates, water consumption rates need to be put into context. Table B-31 presents default thresholds for evaluating the rates of gallons of water consumed/gallon of biofuel produced against an estimated petroleum baseline.⁴⁹

Table B-31. Water Consumption Thresholds

Likelihood of hazard	Assessed value	Water consumption threshold
Lowest	1	Water-Positive (Returned > Withdrawal)
Low	2	Net-zero: Returned = Withdrawal
Moderate	3	Greater than Net-zero but less than 4.18 gal/gal biofuel
High	4	Greater than or equal to 4.18 gal/gal biofuel but less than 8.36 gal/gal biofuel
Highest	5	Greater than or equal to 8.36 gal/gal biofuel

METRIC 3: WATER STRESS LEVEL (*NATIONAL OR COUNTY LEVEL*)

The water stress levels metric TAWW versus TARWR in a geographic unit. Currently, this can be estimated at the national level for the United States. However, annual withdrawals are collected by USGS at the county level, as well as for some hydrologic units. If TARWR can eventually be collected for these geographic units, water stress could be estimated at the local or regional level. This could aid with locating proper areas for feedstock acquisition and biofuel production and assessing the impact of these activities on water availability over time.

Key databases and tools for calculating Metric 3 include:

- ◆ AQUASTAT (www.fao.org/nr/water/aquastat/main/index.stm)
 - Provides TAWW and TARWR at the national level
 - TAWW can be divided by TARWR, offering an indicator of water stress at the national level
- ◆ Global Water Tool 2011 (www.wbcsd.org/work-program/sector-projects/water/global-water-tool.aspx)⁵⁰
- ◆ USGS Water Use in the United States Website (water.usgs.gov/watuse/)

⁴⁹ Per the AEPI Report *Quantifying the Army Supply Chain Water Footprint*, the water footprint for converting crude oil to gasoline is estimated, on average, at 4.18 gallons of water per gallon of crude oil are allocated to gasoline (p. 3–25). This is used as the basis for the consumption thresholds for biofuel production.

⁵⁰ In some instances, this tool may be able to obtain renewable water resources per capita. More information can be found at: www.wbcsd.org/work-program/sector-projects/water/gwt/how-does-it-work.aspx.

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- Annual water withdrawals for counties and some hydrologic units can be downloaded.⁵¹ The most recent measurements are for 2005 (data are collected every 5 years). If TARWR becomes available for these geographic units, annual water withdrawals can be divided by TARWR to estimate water stress within a county.

Due to data limitations, Metric 3 can currently only be calculated at the national level. Users can assess US water withdrawal at the national level by utilizing the Food and Agriculture Organization of the United Nations (FAO) AQUASTAT database. One can view a variety of information at the national level, such as arable land, permanent crops, average precipitation, total renewable water resources, agricultural water withdrawal, total water withdrawal, and many other statistics.

When selecting the US under the “Main AQUASTAT Country Database” section, the user can find the TAWW for the US, as well as the TARWR for the United States. Currently, the most recent TAWW data in AQUASTAT are for 2005, while the most recent TARWR measurements are for 2009 (although the TARWR number remains consistent). Dividing the TAWW by the TARWR provides an estimate of water stress (see Table B-12).

$$\text{Water Stress} = \frac{\text{TAWW}}{\text{TARWR}} \times 100$$

The USGS provides online resources to measure water use in the United States. The “USGS Water Use in the United States” website provides users the ability to download county or, for certain states, hydrologic unit level withdrawal data. From the main page, simply click “Download 2005 data for counties” or “selected watersheds.” Downloads include surface and groundwater withdrawal estimates and, in many instances, distinguish between freshwater and saline withdrawals. These measurements are updated every 5 years. Currently, 2005 withdrawal data are available. 2010 withdrawal data are still pending and not expected until 2014.

Since TAWW is provided at the county level, this provides the numerator for the water stress calculation at the local/regional level. Currently, TARWR is not available at the county level. If the water stress calculation denominator (TARWR) becomes available for these geographic units, TAWW may be able to be divided by TARWR as an estimate of water stress at the regional or county levels.

Water stress analysis thresholds (adapted from UN water stress levels) for Metric 6 and provided in Table B-32.

⁵¹ When downloaded from the USGS, all counties within a state are provided in an MS Excel worksheet. While state totals are not provided in the Excel downloads, add all county withdrawals to estimate state water withdrawals.

Table B-32. Water Stress Thresholds^a

Likelihood of hazard	Assessed value	Threshold: TAWW in relation to TARWR
Lowest	1	<5%
Low	2	<10%
Moderate	3	10–20%
High	4	20–40%
Highest	5	>40%

^a Table adjusted from GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

GBEP notes water stress thresholds can be applied at the watershed and national levels.⁵² If TARWR estimates are found to be available at the county or state level, we assume these thresholds can be used to estimate water stress at these geographic units, as well.

METRIC 4: WATER WITHDRAWAL RATES (STATE OR COUNTY LEVELS)

This metric assesses changes in groundwater and surface water withdrawals over a 5-year period. Trending changes in groundwater withdrawal is important, as rapid increases in groundwater withdrawal indicate that use of groundwater may not be a sustainable way of addressing greater water demand or surface water supply changes.⁵³

USGS data can be used to assess broader changes in water withdrawal for both groundwater and surface water. Key measurements, databases, and tools for Metric 4 include:

- ◆ “USGS Water Use in the United States” Website (water.usgs.gov/watuse/).

County-level water use is measured every 5 years so withdrawal changes over 5-year periods can be calculated.

To calculate changes in both groundwater and surface water withdrawals, for instance between 2000 to 2005, download the 2000 and 2005 county-level data for a specific state from the “USGS Water Use in the United States” Website. Pick the applicable county and, for groundwater, select the “Total, ground-water with-

⁵² See footnote 39, this appendix, p. 61 (GBEP).

⁵³ Sustainable Installations Regional Resource Assessment (SIRRA), “Groundwater Withdrawals 5-Year Change,” accessed January 6, 2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/groundwater-withdrawals-5-year-change.

drawals, total, in Mgal/d” (TO-WGWT₀) field in each file. Then, use the following calculation to determine the percent change over this period:⁵⁴

$$\% \text{ Change} = \frac{(2005 \text{ TO-WGWT}_0) - (2000 \text{ TO-WGWT}_0)}{(2000 \text{ TO-WGWT}_0)} \times 100$$

For changes in surface water, pick the county interest and select the “Total surface-water withdrawals, total, in Mgal/d” (TO-WSWT₀) field in each. Then, use the following calculation to determine the percent change over this period:

$$\% \text{ Change} = \frac{(2005 \text{ TO-WSWT}_0) - (2000 \text{ TO-WSWT}_0)}{(2000 \text{ TO-WSWT}_0)} \times 100$$

Aside from a small subset of states that provide data at the hydrologic unit level, most data are provided at the county level. Given that much of these data are only available at the county level, county should be used as the default geographic unit. If these data are or become available by hydrologic unit, the watershed would be used as it is a more appropriate geographic unit. Since watersheds often encompass more than one county,⁵⁵ looking at the watershed as a whole may provide a better indicator of the regional water supply sensitivity.

As USGS water withdrawal level data are only updated every 5 years, the most recent USGS measurements are assumed to be sufficiently accurate for Level III screening purposes. This is one limitation associated with using USGS water use data. Once the 2010 water use measurements are released, those data will be available to use for assessing water quantity. Another limitation for USGS withdrawal data, especially for years prior to 2005, is that some groundwater and surface water fields or totals may not be provided for all counties.

Table B-33 presents groundwater and surface water withdrawal 5-year change thresholds.

*Table B-33 Groundwater and Surface Water Withdrawal
5-Year Change Levels^a*

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Less than 0% change
Low	2	At least 0 but less than 25% change
Moderate	3	At least 25 but less than 50% change
High	4	At least 50 but less than 100% change
Highest	5	100% or more change

^a See Note 17 (SIRRA, “Groundwater Withdrawals 5-Year Change”).

⁵⁴ Ibid.

⁵⁵ Ibid.

METRIC 5: STREAMFLOW/DISCHARGE (WATERSHED, COUNTY, OR WATERBODY LEVELS)

Metric 5 monitors changes in stream discharge levels over time, which can be indicative of stream vulnerability. If stream discharge levels increase greatly over a specific period, it could result in flooding, while if stream discharge levels decrease significantly, it could result in issues concerning water availability.⁵⁶ Stream discharge levels can also be used to identify areas with occasional or chronic low flow.

Key databases for calculating Metric 5 include:

- ◆ USGS National Water Information System (NWIS) (waterdata.usgs.gov/nwis) can provide daily, monthly, or annual means for stream discharge.

The USGS NWIS can be used to establish baseline streamflow as well as to monitor streamflow changes after feedstock or biofuel production begins. “Changes in base flow can reflect consumptive water use in feedstock production. For this purpose, base flow should be considered throughout the growing season.”⁵⁷ Using the USGS NWIS, review daily, monthly, or annual means for stream discharge (measured in ft³/s) by clicking on the “Surface water” selection from the main page, choosing “Daily,” “Monthly,” or “Annual” statistics, and, then, defining the parameters and time frame for the site you wish to assess. Discharge measurements may not be available for all years at all sites.

For the Metric 5 analysis, annual means can be used to estimate change in streamflow over a specific period of time. For instance, use the USGS NWIS to calculate annual stream discharge for 2005 to 2010 at a measurement site, and calculate the percentage change over that period:

$$\% \text{ Change} = \frac{(\text{2010 Discharge}) - (\text{2005 Discharge})}{(\text{2005 Discharge})} \times 100$$

The percentage can be used to indicate the vulnerability of streamflow at the site measured (see Table B-34). Discharge totals downloaded from the USGS NWIS (daily, monthly, or annual) can also provide an indication of low flow sensitivity at a given site (see Table B-35).

There are two thresholds used to assess Metric 5. First, vulnerability of a stream or river flow will be measured based on change to baseflow at feedstock cultivation and biorefinery sites as well as at sites downstream from these sites.

⁵⁶ SIRRA, “Streamflow 5-Year Change,” accessed January 6, 2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/streamflow-5-year-change.

⁵⁷ See footnote 40, this appendix, (McBride).

Table B-34. Change to Stream Discharge Levels^a

Likelihood of hazard	Assessed value	Threshold
Lowest	1	At least -15 but less than 15% change
Low	2	At least -30 but less than -15% change OR at least 15 but less than 30% change
Moderate	3	At least -50 but less than -30% change OR at least 30 but less than 50% change
High	4	At least -100 but less than -50% change OR at least 50 but less than 100% change
Highest	5	Less than -100% change OR at least 100% change

^a See Note 17 (SIRRA, “Streamflow 5-Year Change”).

The Baseflow Index (BFI), or the contribution to total streamflow discharge by groundwater, should be measured against the low flow sensitivity scale presented in Table 35. “Baseflow represents the amount of sustainable flow in the channel and is thus an important consideration when evaluating the health of a stream.”⁵⁸ The BFI is calculated as follows:

$$\text{BFI} = \frac{(\text{Groundwater Discharge})}{(\text{Total Flow})} \times 100$$

For a 2003 report, USGS calculated baseflows in the United States. Data are available for the continental US from the USGS website (water.usgs.gov/GIS/metadata/usgswrd/XML/bfi48grd.xml). Baseflows from 2003 are assumed to be current until USGS releases an update, as “long-term average baseflows are unlikely to fluctuate.”⁵⁹

Table B-35. Low Flow Sensitivity Measurements^a

Likelihood of Hazard	Assessed Value	Threshold
Lowest	1	Greater than 85 but at most 100 BFI
Low	2	Greater than 70 but at most 85 BFI
Moderate	3	Greater than 50 but at most 70 BFI
High	4	Greater than 25 but at most 50 BFI
Highest	5	25 or less BFI

^a See Note 22 [SIRRA, “Low Flow Sensitivity (Updated)”].

⁵⁸ SIRRA, “Low Flow Sensitivity (Updated),” accessed January 11, 2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/low-flow-sensitivity-updated.

⁵⁹ Ibid.

METRIC 6: PEAK STORM FLOW (REGIONAL AND LOCAL IMPACTS)

Increased peak storm flows over time can be indicative of problems with soil, such as reduced water holding capacity.⁶⁰

The key database and tool for calculating Metric 6 include:

- ◆ USGS NWIS (waterdata.usgs.gov/nwis) can provide:
 - Peak streamflow for defined periods
 - Changes in peak streamflow
 - Comparisons peak streamflow with historical peak streamflow.
- ◆ Automated Geospatial Watershed Assessment (AGWA) Tool (www.tucson.ars.ag.gov/agwa/index.php/home-mainmenu-1).⁶¹

USGS NWIS offers historical data for peak streamflows for states, which can be viewed by county or by hydrologic unit. Peak streamflow can be monitored and compared to historical peak streamflow data to detect changes after feedstock and biofuel production begins.

Using the USGS NWIS, review peak streamflows (measured in ft³/s) for specified periods of time by clicking on the “Surface water” selection from the main page, choosing “Peak-flow data” statistics, and then defining the parameters and time frame for the site you wish to assess. Then, calculate peak streamflow for water years and estimate the percent change as previously elaborated in Metric 5. For instance, when assessing the peak streamflow change from 2005 to 2010:

$$\% \text{ Change} = \frac{(\text{2010 Peak Streamflow}) - (\text{2005 Peak Streamflow})}{(\text{2005 Peak Streamflow})} \times 100$$

Note that this information may not be available for all counties or hydrologic units. However, if available, peak streamflow should be monitored. USGS NWIS does not specifically measure peak storm flow. For the purposes of this metric, we assume that peak streamflow serves as a proxy for peak storm flow.

As the percent change for stream discharge (annual average) and peak streamflow (overall annual peak), the same vulnerability thresholds are used. See Table 8 above for the vulnerability thresholds.

⁶⁰ See footnote 40, this appendix, (McBride).

⁶¹ Various output variables from two models (KINEROS and SWAT) can be displayed through the AGWA tool, including peak flow. Additional information about using this tool and system requirements can be found at: www.tucson.ars.ag.gov/agwa/index.php/about-mainmenu-26.

METRIC 7: WATER MANAGEMENT PLAN (PRODUCER LEVEL)

Metric 7 focuses on common water quantity risk mitigation measure that can be used to reduce water use associated with a biofuel production pathways. The key qualitative question to address Metric 7 is:

- ◆ Do the crop producer(s) and biorefiner(s) have Water Management Plans in place?

It simply asks whether the party(ies) involved (feedstock producers, biorefinery operators, etc.) have a water management plan in place as this may help ensure water-efficient practices are considered.

If all parties involved in the supply chain have Water Managements Plans in place, this metric would necessitate a reassessment of Metrics 1 and/or 2. It would result in a hazard and, ultimately, a reduced risk rating.

GENERAL CONSIDERATIONS, ASSUMPTIONS, AND UNCERTAINTIES

As USGS hydrologic unit data are not available for all states, county-level data will need to be used for several of the metrics. If the county is used as the geographic unit, the location of feedstock production and biofuel processing must be noted. If feedstock acquisition takes place in one county, while biofuel production takes place in another county, calculating water quantity will involve using different baseline numbers for the two processes based on the county where each process takes place.

Likewise, distinguishing between renewable and non-renewable water resources, as well as calculating water consumption (versus water withdrawal) poses challenges and uncertainty in our water quantity calculations. If TARWR measurements become available at the county level, then TAWW at the county level can be divided by TARWR to estimate water stress within a county.

Future steps should involve filling in data gaps, such as obtaining water use statistics by watershed and TARWR data for counties, states, and watersheds (once water withdrawal is defined by watershed). If water use data become available by watershed, identify watershed locations at the EPA Water Information Network (water.epa.gov/type/watersheds/index.cfm). Since annual water withdrawal is measured every 5 years for counties and some hydrologic units, measuring TARWR within these geographic units will allow the user to assess water stress within the geographic unit by dividing TAWW by TARWR. In addition, it will be beneficial if it becomes possible to measure or monitor water use more frequently.

Resources, SMEs, and Capabilities

KEYSTONE RESOURCES

AGWA Tool (www.tucson.ars.ag.gov/agwa/index.php/home-mainmenu-1)

AQUASTAT (www.fao.org/nr/water/aquastat/main/index.stm)

EPA Water Information Network (water.epa.gov/type/watersheds/index.cfm)

GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf

Global Water Tool 2011 (www.wbcds.org/work-program/sector-projects/water/global-water-tool.aspx)

SIRRA “Groundwater Withdrawals 5-Year Change” (datacenter.leadgroup.com/sirra/indicator-tabular-data/water/groundwater-withdrawals-5-year-change)

SIRRA “Low Flow Sensitivity” (datacenter.leadgroup.com/sirra/indicator-tabular-data/water/lowflow.html)

SIRRA “Streamflow 5-Year Change” (datacenter.leadgroup.com/sirra/indicator-tabular-data/water/streamflow-5-year-change)

USDA ARS Water Database (www.ars.usda.gov/Main/docs.htm?docid=9696)

USGS NWIS (waterdata.usgs.gov/nwis)

USGS Water Use in the United States Website (water.usgs.gov/watuse/)

Water Footprint Assessment Manual (www.waterfootprint.org/?page=files/WaterFootprintAssessmentManual)

Water Footprint Network (www.waterfootprint.org/)

Water Footprint Network WaterStat Database
(www.waterfootprint.org/?page=files/WaterStat-ProductWaterFootprints)

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SUPPLEMENTARY SUPPORTING CAPABILITIES

NWIS offers real-time streamflow conditions in many locations throughout the United States. Real-time data are included for water measurement stations with at least 30 years worth of data, and can be obtained by clicking the “Real-time data” selection on the main page. The real-time data map of the United States displays colored dots, which depict daily streamflow as percentiles, which are “computed from the period of record for the current day of the year.”⁶² The user can select different water measurement locations (states, followed by specific measuring stations) throughout the United States. Once a specific water measurement location is chosen, the user can view a line graph displaying discharge (ft³/s) relative to the median daily discharge statistic for however many years of measurements have been recorded. One can go back as many as 120 days for this line graph, allowing the user to determine whether streamflow has been consistently above or below median levels.

“USGS Water Use in the United States” can identify areas in the United States with below-average streamflow. On the left side of the screen, click “Drought” under the map of the United States. Users have the ability to view maps with state drought information or areas in the United States with 7-day, 14-day, 28-day, or monthly below normal streamflow. The maps give the user the ability to click on a specific state and obtain additional information about the drought areas. This feature may be useful in establishing base streamflow, as it may help the user identify streams or rivers with recent below-average stream discharge.

References

AEPI, *Quantifying the Army Supply Chain Water Footprint*, December 2011.

⁶² USGS, “USGS Real-Time Water Data for the Nation,” accessed January 4, 2012, <http://waterdata.usgs.gov/nwis/rt>.

- AGWA, "About AGWA," accessed 01/11/2012, www.tucson.ars.ag.gov/agwa/index.php/about-mainmenu-26.
- GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.
- Gleick, Peter H., "Water and Energy," *Annual Review Energy Environment* 19 (1994), pp. 267–299.
- King, Carey W. and Webber, Michael E., "Supporting Information for the manuscript: The Water Intensity of Transportation," pp. S1–S31.
- King, Carey W. and Webber, Michael E., "The Water Intensity of the Plugged-In Automotive Economy," *Environmental Science & Technology* 42 (2008), pp. 4305–4311.
- King, Carey W. and Webber, Michael E., "Water Intensity of Transportation," *Environmental Science & Technology* 42:21 (2008), pp. 7866–7872.
- McBride, Allen C., et al. "Indicators to support environmental sustainability of bioenergy systems." *Ecological Indicators* 11 (2011), pp. 1277–1289.
- Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands, www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf.
- SIRRA, "Groundwater Withdrawals 5-Year Change," accessed 01/06/2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/groundwater-withdrawals-5-year-change.
- SIRRA, "Low Flow Sensitivity (Updated)," accessed 01/11/2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/low-flow-sensitivity-updated.
- SIRRA, "Streamflow 5-Year Change," accessed 01/06/2012, datacenter.leadgroup.com/sirra/indicator-tabular-data/water/streamflow-5-year-change.
- USGS, "Estimated Use of Water in the United States in 2005," Circular 1344, 2009.
- USGS, "USGS Real-Time Water Data for the Nation," accessed 01/04/2012, waterdata.usgs.gov/nwis/rt.
- USGS, "Tutorial Home: Do you need help finding USGS data about your watershed?" accessed 01/04/2012, nwis.waterdata.usgs.gov/tutorial/.

WBCSD, “How Does It Work?” accessed 01/11/2012, www.wbcsd.org/work-program/sector-projects/water/gwt/how-does-it-work.aspx.

Water Quality

Pillar	Environmental
Criteria	Water
Indicator	Water Quality

Water quality, as defined by the USGS is “a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics, usually in respect to its suitability for a particular purpose.”⁶³ Water quality is frequently defined and measured against various federal, state, and local regulatory standards based upon the water’s specific uses (e.g., drinking water, agriculture, recreation, maintenance of ecosystem health, etc.). Federal standards include the CWA of 1990 and the SDWA of 1974. In addition, states, counties, or local municipalities often have their own drinking water standards and monitoring.

This indicator is most applicable at the watershed, regional, and local levels. It is driven by and influences several other indicators including soil quantity, productivity, and water quantity. For example, water quality can be impacted by land use and cover, fertilizer applications, and soil conditions.⁶⁴ Likewise, water quality related treatment, monitoring, management, and regulatory compliance can represent significant operational costs to consider.



Water quality can change quite rapidly (daily and hourly) and is not only impacted by local activities but upstream factors, such as industrial effluents, non-point land use, and nutrient management practices. Biomass production, preprocessing, and biofuel production can impact water quality in lakes, rivers, estuaries, and aquifers and have potential consequences for aquatic ecosystem health, human use, and consumption. Biofuel pathway type, siting, and management practices all interact to degrade or improve local aquifers, water bodies, and watersheds.⁶⁵

⁶³ USGS, *A Primer on Water Quality*, March 2001, <http://pubs.usgs.gov/fs/fs-027-01/>.

⁶⁴ McBride, Allen C., et al., “Indicators to support environmental sustainability of bioenergy systems,” *Ecological Indicators* 11 (2011), p. 1281.

⁶⁵ Society of Chemical Industry and John Wiley & Sons, Ltd., *Water quality assessment of bioenergy production*, June 12, 2011, <http://www.treesearch.fs.fed.us/pubs/38739>.

RELEVANCE AND RATIONALE

Water quality is a highly visible issue that directly impacts human health. As a result, it is subject to the authority of numerous federal, state, and local regulations and is directly mentioned as a topic of concern in several US biofuel statutes, relevant USG policies, and DoD plans. Likewise, the vast majority of biofuel sustainability frameworks and standards focus on water quality and the management of its impacts.

Table B-36. Water Quality Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
Biomass Research and Development Act of 2000		Yes	
2002 Farm Bill	Yes		
EISA of 2007		Yes	
Food, Conservation, and Energy Act of 2008		Yes	
National Environmental Protection Act of 1970		Yes	
CWA		Yes	Yes
Emergency Planning and Community Right-to-Know Act of 1986	Yes		
USG Policy Relevance			
EO 13514	Yes		
DoD and Service Policy Relevance			
DoD SSPP FY10	Yes		
DoD SSPP FY11	Yes		

A focus on water quality is widespread, with criteria appearing in virtually every biofuel sustainability framework, approach, and industry standards (Table B-37).

Table B-37. Water Quality in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	Yes
DOE Biomass Program, Sustainability Platform	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	Yes
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	Yes
GBEP	Yes	
ISO 14025 Product Category Rules	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Water quality is one of the key indicators of biofuel environmental sustainability but also one of the most complex. The National Resource Council has suggested that “[a]mong the possible challenges to biofuel development that may not have received appropriate attention are its effects on water and related land resources. The central questions are how water use and water quality are expected to change as the US agricultural portfolio shifts to include more energy crops and as overall agricultural production potentially increases.”⁶⁶ In short, water quality is not only a compliance issue for biomass cultivation, preprocessing, and biorefinery siting but also represents a broader hurdle to market adoption and public acceptance. Growing public concern over tight gas recovery techniques, such as “fracking” is a salient example. Considering this, the following metrics have been selected for the Defense Logistics Agency Energy use to directly assessing and weighting the real risks.

Pathway Characteristics (Likelihood Metrics⁶⁷)

- ◆ Metric 1: Annual Nitrogen and Nitrates Loadings, kg/year
- ◆ Metric 2: Annual Phosphorus Loadings, kg/year
- ◆ Metric 3: Total Biochemical (BOD) and Chemical Oxygen Demand (COD), mg/L

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 4: Water Body Impairment for Nitrogen or Nitrates
 - Local receiving water body or watershed listed as “impaired” for nitrogen or nitrates, Yes/No
 - Total Maximum Daily Load (TMDL) established for nitrogen or nitrates, Yes/No
- ◆ Metric 5: Water Body Impairment for Phosphorus
 - Local receiving water body or watershed listed as “impaired” due to phosphorus pollution, Yes/No

⁶⁶ National Research Council of the National Academies, *Water Implications of Biofuels Production in the United States*, 2008, p. 1, www.nap.edu/catalog.php?record_id=12039.

⁶⁷ Other water quality indicators were considered, such as total suspended solids (TSS) and pathogens for feedstock generation, and temperature, pH, electrical conductivity, and oil and greases for biofuel processing. These are all significant parameters of water quality, but the current metrics focus on nitrogen, phosphorus, and biochemical/chemical oxygen demand at this time because of their applicability to all pathways, regulatory relevance, and supply chain risk management need.

- TMDL established for phosphorous, Yes/No
- ◆ Metric 6: Water Body Impairment for BOD/COD
 - Local receiving water body or water shed listed as “impaired” due to BOD/COD or eutrophication, Yes/No
 - TMDL established for BOD/COD, Yes/No

Risk Reduction (Mitigation Metric)

- ◆ Metric 7: Land, Soil and Water Best Management Practices (BMPs) and Plans
 - BMPs, such as precision agricultural, soil erosion prevention, and nutrient pollution reduction techniques,⁶⁸ are in place, Yes/No
 - Stormwater Pollution Prevention Plan (SWPPP) is in place, Yes/No

These water quality metrics are most relevant to the feedstock cultivation and bio-fuel production stages of the fuel production life cycle (Table B-38).

Table B-38. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Nitrogen or Nitrates Loadings	Yes	Minimal	Yes	Minimal	Minimal
Metric 2: Phosphorus Loadings	Yes	Minimal	Yes	Minimal	Minimal
Metric 3: Total BOD/COD	Minimal	Minimal	Yes	Minimal	Minimal
Metric 4: Water Body Impairment or Regulation for Nitrogen or Nitrates	Yes	Minimal	Yes	Minimal	Minimal
Metric 5: Water Body Impairment or Regulation for Phosphorus	Yes	Minimal	Yes	Minimal	Minimal
Metric 6: Water Body Impairment or Regulation for BOD/COD	Minimal	Minimal	Yes	Minimal	Minimal
Metric 7: Land, Soil, and Water BMPs and Plans	Yes	Minimal	Yes	Minimal	Minimal

⁶⁸ National Research Council of the National Academies, *Water Implications of Biofuels Production in the United States*, 2008, p. 1, www.nap.edu/catalog.php?record_id=12039.

MEASUREMENT AND ANALYSIS APPROACH

A general trend within agricultural watersheds indicates that 1) surface soil is increasingly disturbed and “exposed to the elements,” and 2) amounts of fertilizer nutrients are growing, both increasing the potential for soil erosion and nutrient export. Major factors and activities that influence non-point pollution nutrient flux include soil type, crop type, pasture and grazing operations, management practices, animal feedlots, and manure storage facilities.

In terms of point sources, industrial wastewater effluents from biorefineries can potentially be high in BOD and may be discharged from the processing of production by-products, such as thin stillage, wet distillers’ grains, and dry distillers’ grains with solubles (DDGS). Discharge of high-BOD water to rivers and lakes can be a significant contributor to eutrophication, which is where accelerated decomposition occurs, consumes much of the dissolved oxygen, and asphyxiates aquatic animals (i.e., fish kills).⁶⁹

The direct measurement and monitoring of effluents required by permits provides one of the most reliable means management of these inputs and impacts. However, the time, expense, and effort needed to do so for non-point sources and to derive annual nutrient loading coefficients for specific operations, surface waters, and watersheds have prompted many water quality investigators to rely on values developed in the research literature.⁷⁰ Considering these challenges, the following metric approaches have been developed as a representative means to estimate water hazards, consequences, and mitigations of biomass cultivation, preprocessing, and biofuel production pathways. They provide screening level information but are not a replacement for pathway specific analysis or monitoring required for permitting and reporting compliance.

Metric 1: Nitrogen or Nitrates Loadings (National, Watershed, Regional, or Local Levels)

Metric 1 directly focuses on the quantity of nitrogen and nitrate compounds being generated and ultimately contributed to the local receiving waters. This metric is greatly impacted by the soil type, crop, cropping system, amount and type of fertilizer, management practices, and treatment technologies used.

Key measurements, databases, and approaches for calculating Metric 1 include:

- ◆ Export Coefficient Equation⁷¹

⁶⁹ Ibid.

⁷⁰ Michael N. Beaulac and Kenneth H. Reckhow, “An Examination of Land Use – Nutrient Export Relationships,” *Water Resources Bulletin* Vol. 18, No. 6 1982: 1013–1024.

⁷¹ EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008, Chapter 8, http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents.

- ◆ EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008 (http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents)
- ◆ EPA, TMDL documents for local receiving water to obtain local nutrient export coefficients, if applicable and available (<http://www.epa.gov/waters/ir/>)
- ◆ EPA, NPDES or local sanitary authority permits, if applicable and available (<http://www.epa.gov/enviro/facts/pes-icis/search.html>).

ESTIMATE NITROGEN OR NITRATES LOADINGS FOR FEEDSTOCK PRODUCTION

Equation 1's export coefficient equation is used to estimate annual nitrogen loads for feedstock cultivation and production. This equation is a simplified pollutant runoff model as all of necessary factors effecting pollutant movement are combined into a single export coefficient.⁷²

Equation 1. Export Coefficient Equation

$$\text{Total pollutant load } \left(\frac{kg}{yr} \right) = \text{land use area (ha)} \times \text{export coefficient } \left(\frac{kg}{ha \cdot yr} \right)$$

Table B-39 provides example national export coefficients for cover/feedstock types.

Table B-39. Example National Nitrogen Export Coefficients^a

Crop	Export coefficient
Forest Cover	1.8
Corn	11.1
Soybeans	12.5
Feedlot or Dairy	2,900

^a Nitrogen export coefficient for forest, corn, soybeans, and feedlots/dairy are from North Carolina State University's Water, Soil, and Hydro-Environmental Decision Support System (WATERSHEDSS) Pollutant Budget Estimation Form (<http://www.water.ncsu.edu/watershedss/>).

Export coefficients for crops vary greatly throughout the country as they depend upon factors, such as soil, precipitation, slope, etc. Therefore, it is important to identify export coefficients representative for associated watershed, region, and locality as such information becomes available. Regional export coefficients may already be available from studies conducted in or from a neighboring watershed.

⁷² It should be noted that, despite their wide acceptance, nutrient loading estimates in the literature can exhibit considerable variation and, hence, uncertainty.

Lin 2004⁷³ summarizes and reviews many of the published export coefficients at both the national and regional level so they can be applied to estimate pollutant loadings into specific watersheds. While it does not identify the crop specific export coefficients, this resource may be combined to calibrate feedstock specific studies to refine export coefficients for a particular pathway. In addition, if the local receiving water body is listed as impaired (see Metrics 4–6), EPA or state regulatory websites should be consulted to determine if the TMDL documentation include the watershed specific report and supporting modeling results. These materials may identify the relevant export coefficients tailored to that watershed for several categories, such as generalized land use types (e.g., pasture, etc.). If regional or local export coefficients are not available, the national export coefficients in Table B-28 can be used in the interim with the caveat that these values involve greater amount of uncertainty and may not accurately reflect the watershed.

Once the appropriate nitrogen export coefficient is identified, this provides the metric value for evaluating the likelihood of water quality impact. Table B-40 shows hazard thresholds based on the export coefficients provided in Table B-39. However, these threshold levels may change if local nutrient export coefficients are available.

Table B-40. Nitrogen Loading Thresholds for Feedstock Production

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<0
Low	2	2 (e.g., forest cover)
Moderate	3	8 (e.g., corn/soybeans with winter cover crop)
High	4	12 (e.g., corn/soybeans with no winter cover crop)
Highest	5	>1,000 (e.g., intensively managed feedlot or dairy)

ESTIMATE NITROGEN OR NITRATE LOADING FOR BIOFUEL PROCESSING

For preprocessing or biofuel production facilities, it is necessary to determine whether the plant holds an NPDES permit or local sanitary authority discharge permit that identifies nitrogen or nitrates as a pollutant. Once a statement of compliance has been provided, Table B-41 provides the thresholds necessary to determine appropriate likelihood of hazard for nitrogen or nitrates discharge.

⁷³ Lin, J.P., 2004, *Review of Published Export Coefficient and Event Mean Concentration (EMC) Data*, ERDC TN WRAP 04 03, US Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, el.erdc.usace.army.mil/elpubs/pdf/tnwrap04-3.pdf.

Table B-41. Nitrogen or Nitrate Loading Thresholds for Preprocessing and Biofuel Production Facilities

Likelihood of hazard	Assessed value	Threshold
Low	2	Facility is in compliance with applicable regulations and does not require an NPDES or sanitary discharge permit.
Moderate	3	Facility is in compliance and has an NPDES or sanitary discharge permit that does not include nitrogen or nitrates.
Highest	5	Facility is in compliance and has an NPDES or sanitary discharge permit that includes nitrogen or nitrates.

Metric 2: Phosphorus Loadings (National, Watershed, Regional, or Local Levels)

Metric 2 reflects the quantity of phosphorus generated and exported to the local receiving waters as a result of feedstock cultivation, preprocessing, and processing. As with nitrogen and nitrates export coefficients, this metric is greatly impacted by the soil type, crop, cropping system, amount and type of fertilizer, management practices, and treatment technologies utilized.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ Export Coefficient Equation⁷⁴
- ◆ EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008 (http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents)
- ◆ EPA, TMDL documents for local receiving water to obtain local nutrient export coefficients, as applicable (<http://www.epa.gov/waters/ir/>)
- ◆ EPA, NPDES or local sanitary authority permits, as applicable (<http://www.epa.gov/enviro/facts/pes-icis/search.html>).

ESTIMATE PHOSPHORUS LOADING FOR FEEDSTOCK PRODUCTION

For estimating annual phosphorus export coefficients, the same methods described in Metric 1 for feedstock production can be used. The only key difference is the nutrient export coefficients identified or developed should be for phosphorus. Table B-42 presents national phosphorus export coefficients for several example feedstocks.

⁷⁴ EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008, Chapter 8, http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents.

Table B-42. Example National Phosphorus Export Coefficients^a

Crop	Export Coefficient
Forest	0.11
Corn	2
Soybeans	4.6
Feedlot or Dairy	220

^a Phosphorus export coefficient for forest, soybeans, corn, and feedlot/dairy are from North Carolina State University's WATERSHEDSS Pollutant Budget Estimation Form (<http://www.water.ncsu.edu/watershedss/>).

As with nitrogen export coefficients, it is necessary to identify the appropriate phosphorus export coefficients most applicable to associated watershed. As previously noted, regional export coefficients may be available from studies in specific watersheds or those in close proximity. Likewise, if the local receiving water body is listed as impaired, EPA or state regulatory website may provide the TMDL documents that include the watershed-, regional-, or local water body-specific export coefficients for phosphorous. If watershed, regional, or local export coefficients are not available, national export coefficients for phosphorous found in Table B-42 may be used as proxies with the caveat that they may not be reflective of local conditions.

Once an appropriate phosphorus export coefficient for the feedstock is identified, the thresholds in Table B-43 are applied to determine the level of hazard posed by the production system.

Table B-43. Phosphorus Loading Thresholds for Feedstock Production

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<0
Low	2	0.1 (e.g., forest cover)
Moderate	3	1 (e.g., corn/soybeans with winter cover crop)
High	4	2 (e.g., corn/soybeans with no winter cover crop)
Highest	5	>200 (e.g., intensively managed feedlot or dairy)

ESTIMATE PHOSPHORUS LOADING FOR BIOFUEL PROCESSING

As with the Metric 1 approach for preprocessing or biofuel production facilities, it is necessary to determine whether the plant holds an NPDES permit or local sanitary authority discharge permit that identifies phosphorous as a pollutant. Once a statement of compliance has been provided, Table B-44 provides the thresholds necessary to determine appropriate likelihood of hazard for phosphorous discharges.

Table B-44. Phosphorus Loading Thresholds for Preprocessing and Biofuel Production Facilities

Likelihood of hazard	Assessed value	Threshold
Low	2	Facility is in compliance with applicable regulations and does not require an NPDES or sanitary discharge permit.
Moderate	3	Facility is in compliance and has an NPDES or sanitary discharge permit that does not include phosphorous.
Highest	5	Facility is in compliance and has an NPDES or sanitary discharge permit that includes phosphorous.

Metric 3: Total BOD/COD (National, Watershed, Regional, or Local Levels)

Metric 3 focuses on the organic matter present in facility effluent and its potential contribution of BOD/COD potential when released into local receiving waters. BOD is a measure of the amount of oxygen bacteria will ultimately consume when decomposing the organic matter present under aerobic conditions. COD is likewise a measure of the total quantity of oxygen required to theoretically oxidize all organic material into carbon dioxide but does not differentiate between biologically available and inert organic matter.⁷⁵ Industrial effluent discharges with high BOD or COD values can be a significant cause or contributor to water body eutrophication. These effluents' organic matter accelerates bacterial decomposition that consumes the majority of the dissolved oxygen in the water, which, ultimately, asphyxiates aquatic animals (i.e., fish kills).

This metric is primarily focused on preprocessing and biofuel production activities. As such, it is highly dependent on the feedstock and process type, effluent treatment technology, and management practices applied.

Key measurements, databases, and tools to calculate Metric 3 include:

- ◆ EPA, NPDES or local sanitary authority permits, as applicable (<http://www.epa.gov/enviro/facts/pes-icis/search.html>).

To determine BOD/COD, first determine whether the preprocessing and biofuel production facility has applied for or maintains an NPDES or local sanitary authority permit. If a permit is required, determine whether the permit identifies BOD or COD as a pollutant. Once a statement of compliance has been provided, Table B-45 provides the thresholds necessary to determine appropriate likelihood of hazard for BOD or COD discharges.

⁷⁵ Brown and Caldwell, "Watershed Protection Plan Development Guidebook, Appendix B, Prepared for Northeast Georgia Regional Development Center," May 2001.

Table B-45. BOD or COD Thresholds

Likelihood of hazard	Assessed value	Threshold
Low	2	Facility is in compliance with applicable regulations and does not require an NPDES or sanitary discharge permit.
Moderate	3	Facility is in compliance and has an NPDES or sanitary discharge permit that does not include BOD or COD.
Highest	5	Facility is in compliance and has an NPDES or sanitary discharge permit that includes BOD or COD.

Metrics 4: Water Body Impairment or Regulation for Nitrogen or Nitrates (Watershed or Local Levels)

As a consequence component, Metric 4's focus is on whether the local water body or watershed is listed as impaired because of nitrogen or nitrate pollution. Section 303(d) of the CWA requires states, territories, and authorized tribes to develop lists of impaired waters. This designation indicates that these waters are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. If a receiving water body is listed as impaired for a particular pollutant, this is indicative of a high regional or local sensitivity for the identified pollutant, such as nitrogen and nitrates. Section 303(d) likewise requires that these jurisdictions establish priority lists for these water bodies and develop TMDLs for the specific pollutants of concern. In short, a TMDL is a calculation of the maximum amount of a particular pollutant that a waterbody can receive and still safely meet established water quality standards.⁷⁶

Key measurements, databases, and tools for calculating Metrics 4–6 include:

- ◆ EPA's Water Quality Assessment and TMDLs (<http://www.epa.gov/waters/ir/>)
- ◆ State regulatory authorities (e.g., Illinois TMDL program is managed by the Illinois Environmental Protection Agency).

Once a pathway's location(s) is identified, EPA's Water Quality Assessment and TMDL Information portal should be used to identify whether the local receiving waters or watersheds are listed as impaired for nitrogen or nitrates. Further, determine if a TMDL for these pollutants has been established or is under development for these water bodies or watersheds.

Apply these findings against the thresholds presented in Table B-46 to determine the resultant consequence of this pollutant hazard.

⁷⁶ EPA, "Impaired Waters and Total Maximum Daily Loads," September 2012, <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm>.

Table B-46. Nitrogen or Nitrate Thresholds for Watershed or Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Low	2	Local receiving water bodies and watershed(s) are not on impaired list due to nitrogen or nitrates.
Moderate	3	Local receiving water bodies and watershed(s) are listed on the impaired list due to nitrogen or nitrates, but TMDLs for these pollutants have not been established.
Highest	5	Nitrogen or nitrates TMDL is under development or already established for the local water bodies and watershed(s).

Metrics 5: Water Body Impairment or Regulation for Phosphorus (Watershed or Local Levels)

Metric 5 reflects the sensitivity of the local receiving waters and watershed to phosphorous pollution releases. As described in Metric 4, EPA's Water Quality Assessment and TMDL Information portal should be used to identify whether the local receiving waters or watersheds are listed as impaired for phosphorous pollution and whether they are subject to a pending or existing TMDL. As with Metric 4, apply these findings using the thresholds presented in Table B-47 and determine the resulting consequence rating for this hazard.

Table B-47. Phosphorous Thresholds for Watershed or Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Low	2	Local receiving water bodies and watershed(s) are not on impaired list due to phosphorous.
Moderate	3	Local receiving water bodies and watershed(s) are listed on the impaired list due to phosphorous, but a TMDL for this pollutant has not been established.
Highest	5	A phosphorous TMDL is under development or already established for the local water bodies and watershed(s).

Metrics 6: Water Body Impairment or Regulation for BOD/COD (Watershed or Local Levels)

Metric 6 focuses on the sensitivity of local receiving waters and watersheds to BOD or COD in effluent releases. As described in Metric 4 and 5, EPA's Water Quality Assessment and TMDL Information portal should be used to identify whether local receiving waters or watersheds are listed as impaired for BOD or COD as well as whether they are subject to pending or existing TMDL for this type of pollution. Once again, it is necessary to apply these findings against the thresholds presented in Table B-48 and determine the resulting rating for this consequence metric.

Table B-48. BOD/COD Thresholds for Watershed or Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Low	2	Local receiving water bodies and watershed(s) are not on impaired list due to BOD/COD.
Moderate	3	Local receiving water bodies and watershed(s) are listed on the impaired list due to BOD/COD, but TMDLs for these pollutants have not been established.
Highest	5	A BOD/COD TMDL is under development or already established for the local water bodies and watershed(s).

Metric 7: Land, Soil, and Water BMPs and Plans (Producer Level)

Metric 7 addresses the water quality risk mitigation measures that can be used to reduce water quality risks associated with biofuel production pathways. The key qualitative questions to address Metric 7 are:

- ◆ For feedstock producers, are BMPs, such as precision agriculture, soil erosion prevention, and nutrient management techniques, in place and utilized?
- ◆ For preprocessing and biofuel production facilities, are SWPPPs in place and realizing effluent pollution reductions?

If 1) feedstock producers are using BMPs and 2) preprocessing and production facilities have SWPPPs, affirmative responses on this mitigation metric would necessitate a reassessment of Metrics 1, 2, and/or 3 hazard ratings. The reassessment may justify a reduction of the raw risk number due to a reduced likelihood hazard and lower impact to local water quality.

General Considerations, Assumptions, and Uncertainties

As previously stated, direct measurement and monitoring of water quality hazards and consequences provides the most reliable management metrics as proposed in this indicator technical sheet. In the absence of a defined location for the biofuel pathway, national or regional export coefficients will be used for a preliminary assessment of the respective technology hazard across the pathway life cycle. However, given the variation in regional, watershed, and local conditions and their impacts on export coefficients, it is important to acknowledge the uncertainty of these national level coefficients. While the metrics suggested in this report are scalable, their accuracy is improved when calculated and tailored for local production conditions. In the case of preprocessing and production facilities, the accuracy (and uncertainty) is limited to that of the testing used to monitor and comply with the permit and regulatory compliance reporting.

In the case of non-point pollution generation (i.e., feedstock production), direct measurement may not be practical or possible. However, there are numerous water quality models available that may provide great fidelity than the national coefficients. These models were not proposed in the metric descriptions above due to their complexity and time resource requirement. But, the various watershed models available are potential options below the national level and discussed in more detail in Chapter 8 of EPA's 2008 *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*.⁷⁷

RESOURCES AND SMES

Keystone Resources

EPA, Envirofacts, Permit Compliance System and Integrated Compliance Information System (<http://www.epa.gov/enviro/facts/pcs-icis/search.html>)

EPA, Surf Your Watershed (<http://cfpub.epa.gov/surf/locate/index.cfm>)

EPA, Water Quality Assessment and TMDLs (<http://www.epa.gov/waters/ir/>)

Lin, J.P., 2004, Review of Published Export Coefficient and Event Mean Concentration (EMC) Data, ERDC TN WRAP 04 03, US Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, (<http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap04-3.pdf>)

North Carolina State, WATERSHEDSS Pollutant Budget Estimation Form (<http://www.water.ncsu.edu/watershedss/>)

Identified SMEs and Organizations

Jeff Arnold, ARS, USDA

John Davis, NRCS, USDA

Bill Keeling, Virginia Department of Conservation and Recreation

Frank Reilly, Senior Consultant, LMI

REFERENCES

Brown and Caldwell, "Watershed Protection Plan Development Guidebook, Appendix B, Prepared for Northeast Georgia Regional Development Center," May 2001.

⁷⁷ EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008, Chapter 8, http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents.

- EPA, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, 2008, Chapter 8, http://water.epa.gov/polwaste/nps/handbook_index.cfm#contents.
- EPA, “Impaired Waters and Total Maximum Daily Loads,” September 2012, <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm>.
- Lin, J.P., 2004, *Review of Published Export Coefficient and Event Mean Concentration (EMC) Data*, ERDC TN WRAP 04 03, US Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, el.erdc.usace.army.mil/elpubs/pdf/tnwrap04-3.pdf.
- McBride, Allen C., et al., “Indicators to support environmental sustainability of bioenergy systems,” *Ecological Indicators* 11 (2011), p. 1281.
- Michael N. Beaulac and Kenneth H. Reckhow, “An Examination of Land Use–Nutrient Export Relationships”, *Water Resources Bulletin* Vol. 18, No. 6 1982: 1013–1024.
- National Research Council of the National Academies, *Water Implications of Bio-fuels Production in the United States*, 2008, www.nap.edu/catalog.php?record_id=12039.
- Society of Chemical Industry and John Wiley & Sons, Ltd. *Water quality assessment of bioenergy production*, June 12, 2011, <http://www.treesearch.fs.fed.us/pubs/38739>.
- USGS, *A Primer on Water Quality*, March 2001, <http://pubs.usgs.gov/fs/fs-027-01/>.

DIRECT LAND USE

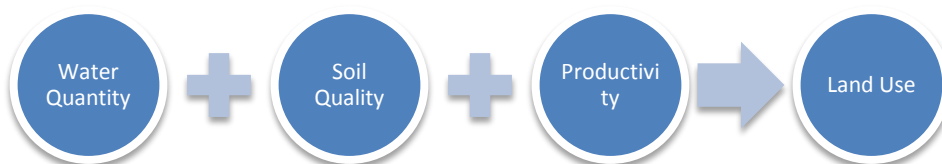
Pillar	Environmental
Criteria	Land
Indicator	Land Use - Direct

Land is one of economics' three "factors of production" and a critical resource necessary for biofuel feedstock and fuel production. While much of the advanced biofuel value chain footprint will likely be analogous to or even collocated with convention petroleum fuel production and distribution infrastructure, biofuel feedstock cultivation and processing presents significant direct and indirect land use demands above and beyond the status quo. As such, land use changes resulting from the cultivation of feedstocks must be considered, quantified, and compared.

In discussing land use, an important distinction is made between direct land use change (DLUC) and ILUC. DLUC is the conversion of natural or existing land use types and modifying it dedicated energy feedstock cultivation and production within the biofuel supply chain.⁷⁸ ILUC focuses more on the economic market-driven displacement of existing products and land uses to meet the demand for a feedstock or biofuel commodity.

Section 201 of EISA 2007 specifically mentions need to consider both "direct emissions and significant indirect emissions such as significant emissions from land use change." However, it is important to note that there are significant differences in the LCA methods used for direct and indirect environmental impacts (i.e., direct = attributional LCA & indirect = models and consequential LCA). In response to EISA, EPA has made progress on ILUC and its GHG emissions, but there is still considerable scientific and policy debate concerning these downstream indirect approaches. As such, land use has been split into two separate sustainability indicators with this technical sheet focusing on DLUC.

DLUC is one of the keystone factors that link several different pillars, criteria, and indicators. Land use is determined by several upstream factors in feedstock production familiar to agricultural production systems.



⁷⁸ EPA, 2011, Biofuels and the Environment: First Triennial Report to Congress, Office of Research and Development, National Center for Environmental Assessment, Washington, DC; EPA/600/R-10/183F. Available online at <http://epa.gov/ncea>.

Natural or irrigation water can be a limiting factor on location as well as the feedstock choices. Likewise, soil quality and productivity have direct impacts on the amount of land needed for cultivating biofuel. If soil quality is good and feedstock productivity is high, then, impacts from direct land use can be reduced because less acreage will be required to grow the same quantities of feedstocks. However, it is important to note that cultivation intensification can also spur greater downstream impacts, such as increased erosion and resultant water quality degradation.



Greater extent of land use changes can likewise have environmental consequences depending on the type of change and management regime applied. In particular, soil is a major carbon sink in most biomes, but factors such as climate, soil type, and plant type produce great variations in the amount of stored carbon. As such, land use change can generate different amortized and annualized life-cycle GHG emissions. Biomes with the highest soil and vegetation carbon pools include boreal forests, tropical forests, and temperate grasslands. In the United States, grasslands cover roughly four million acres.⁷⁹ Habitat conversion and impacts are another downstream impact to be considered, particularly given the EISA Section 201 definition of sustainable biomass (i.e., existing agricultural lands as of 2007 and non-federal forest lands) and in cases where federal NEPA requirements clearly apply.

Relevance and Rationale

Biofuels have been generally considered a low-carbon energy solution that has added benefits of promoting national energy security and independence, spurring economic development, and reducing negative environmental impacts. While tail-pipe GHG and criteria air pollutant emissions from biofuels are often significantly less than conventional petroleum-based fuels, full LCAs are required to estimate total emissions and other potential environmental impacts of these different fuel types. As such, direct land use can be an important component in understanding the stage 1 cultivation emissions. Life-cycle GHG emissions from DLUC are most significant when areas with large carbon sinks are converted to grow biofuel feedstocks. Table B-49 presents the estimated total global carbon stocks held within nine major biomes. EISA's definitional language limits the conversion of "ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest."

⁷⁹ US Forest Service (USFS), *National Grasslands*, 2011, www.fs.fed.us/grasslands/.

Table B-49. Global Carbon Stocks of Major Biomes (Gt C)^a

Biome	Total global carbon stocks (soil + vegetation)
Boreal forest	559
Tropical forest	428
Tropical savannas	330
Temperate grasslands	304
Wetlands	240
Deserts/semi deserts	199
Temperate forest	159
Croplands	131
Tundra	127
Total	2,477

^a Intergovernmental Panel on Climate Change (IPCC), *Special Report, Land Use, Land-Use Change, and Forestry*, 2000, ISBN 92-9169-114-3.

Adapted from: IPCC, *Special Report, Land Use, Land Use Change, and Forestry*, 2000.

However, the statutory and policy drivers include land use considerations that are broader than EISA. Table B-50 identifies several policies and statutes that have relevance to land use change, biofuels, and its implications.

Table B-50. Direct Land Use Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
Biomass Research and Development Act of 2000		Yes	
2002 Farm Bill		Yes	
EISA of 2007		Yes	
National Environmental Protection Act of 1970	Yes		
USG Policy Relevance			
EO 13514	Yes		

In addition to federal drivers, biofuel sustainability frameworks and industry standards commonly include some aspect or criteria focused on land use change. Indicators on direct (and sometimes indirect) land use and change appear in virtually every biofuel sustainability framework, approach, and industry standard reviewed. Table B-51 presents an overview of the broad applicability and inclusion of this indicator.

Table B-51. Direct Land Use in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
DOE Biomass Program, Sustainability Platform	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	
GBEP	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	

Metrics Selected

DLUC metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for quantitative comparisons among drop-in biofuels. At a minimum, the following metrics are required to first determine land use change applicability; and, second, quantification of the amortized annual land use characteristics for feedstock cultivation and conversion pathway.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Additive Infrastructure Footprint, acre(s)/gallon of annual biofuel capacity.
- ◆ Metric 2: Land Area Required for Feedstock Cultivation
 - If waste or off-grade, then, metric 2 is not applicable.
 - If residue or co-product, then, the metric being tracked would be annualize ton feedstock produced/acre or acre(s)/gallon biofuel (*note co-product allocation assumptions*).
 - If crop or forest product, then, the metric being tracked would be annualize bushels feedstock produced/acre, tons feedstock produced/acre, or acre(s)/gallon biofuel.

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 3: Net Land Conversion to Cultivation by Type (within given market region)
 - If cropland (established prior to 2007), the metric being tracked is acres brought into modified food crop rotation system (e.g., camelina insertion into winter wheat fallow rotation) for feedstock production.

-
- If cropland (established prior to 2007), the metric being tracked is acres fully devoted to feedstock production.
 - If croplands being used as pasturelands (established prior to 2007), the metric being tracked is acres brought into feedstock production.
 - If permanent pasturelands (established prior to 2007), the metric being tracked is acres brought into feedstock production.
 - If fallow or managed lands (established prior to 2007), the metric being tracked is acres brought into feedstock production.
 - If previously retired lands (established prior to 2007), the metric being tracked is acres brought into feedstock production.
 - If degraded or contaminated land, the metric being tracked is acres brought into feedstock production.
 - If Conservation Reserve Program (CRP) land, the metric being tracked is acres brought into production.
 - If Environmental Quality Incentives Program (EQIP) land, the metric being tracked is acres brought into production.
 - If managed forest lands (established prior to 2007), the metric being tracked is acres brought into feedstock production.
 - If wilderness forests and grasslands (excluding natural permanent meadows and pastures), peatlands, and wetlands, the metric being tracked is acres brought into production.⁸⁰

Risk Reduction (Mitigation Metrics)

- ◆ Metric 4: Land Managed under Conservation Practices or BMPs, acres/total acres or percentage.
- ◆ Applicability of direct land use has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-52 summarizes the applicability findings.

⁸⁰ Note: Such conversions could represent a violation of EISA 2007 restrictions and NEPA requirements.

Table B-52. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Additive Infrastructure Footprint	Minimal	Yes	Yes	Yes	N/A
Metric 2: Land Area Required for Feedstock Cultivation	Yes	N/A	N/A	N/A	N/A
Metric 3: Net Land Conversion to Cultivation by Type	Yes	N/A	N/A	N/A	N/A
Metric 4: Cultivated Land using Conservation Methods or BMPs	Yes	N/A	N/A	N/A	N/A

Variations in life-cycle boundaries, co-product allocation methodologies, and assumption can generate significant differences in results. Given that this indicator is limited to DLUC, LCA approaches used will primarily be attributional approaches based on the ISO 14040 series of standards.

Measurement and Analysis Approach

METRIC 1: ADDITIVE INFRASTRUCTURE FOOTPRINT

Metric 1 assesses the land required to develop new infrastructure throughout the feedstock and fuel production life cycle. For example, stage # 2 infrastructure could include new roads and feedstock processing facilities. Stage # 3 could include the quantity of acreage necessary for the new biorefinery. New infrastructure built will permanently convert land to industrial or commercial use and change its physical characteristics so it is considered separate from the land use change in feedstock production, which is captured under Metric 2.

Key data and resources for calculating Metric 1 may include construction project related NEPA documentation. Projects directed by or funded with federal funds require the NEPA process and some level of review. Findings of No Significant Impact (FONSI) entail a streamlined review for projects with minimal impacts but may not be appropriate for the scope and extent of a major construction project, such as a new biorefinery. An Environmental Assessment (EA) or an Environmental Impact Statement (EIS) may be required depending upon the proposed project. In all cases, an estimated land footprint will be part of the project plan and NEPA process and, as a result, can be leveraged to provide an initial estimate.

Table B-53. Additive Infrastructure Footprint Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	No additional land use, utilizes existing infrastructure
Low	2	Minor infrastructure upgrades at existing production site
Moderate	3	New infrastructure/facility (<5 acres) co-located with pre-existing production site
High	4	New infrastructure/facility (<5 acres) at greenfield site
Highest	5	New infrastructure/facility (>5 acres) at greenfield site

METRIC 2: LAND AREA REQUIRED FOR FEEDSTOCK CULTIVATION (NATIONAL, REGIONAL, OR COUNTY LEVELS)

This metric is a keystone variable not only required to assess Metric # 3 but also as an intermediate factor (or assumption) needed to calculate life-cycle GHG, productivity, soil quantity, water, quality, etc. While some feedstock effectively reflect no direct cultivation land use (wastes, off-spec products, etc.), biomass production requires land area to grow feedstock crops, forest products, residues, or co-products.

Metric 2 is closely linked with productivity and needs to consider factors, such as cultivation and rotation approach utilized (primary crop, rotational crop, residue, or co-product), growing period (season, annual, perennial), and cultivation regime (intensive, till, no-till, etc.), where such information is available. Ultimately, these factors must be distilled to annual production intensity metrics. Identifying feedstock productivity will also inform a better energy output comparison among different biofuel feedstock options.⁸¹

Key measurements, databases, and tools for calculating Metric 2 include:

- ◆ DOE ANL GREET (greet.es.anl.gov/)
- ◆ USDA National Agricultural Statistics Service (NASS), (www.nass.usda.gov/Data_and_Statistics/index.asp)
- ◆ USDA ARS Extension Literature (www.ars.usda.gov/Research/Research.htm)
- ◆ USFS Forest Inventory and Analysis Program (www.fia.fs.fed.us/).
- ◆ NASS conducts monthly and annual surveys of agricultural production, supply, prices, and other data necessary for assessing agricultural operations. NASS is responsible for preparing all official USDA data and pro-

⁸¹ Initial determination of feedstock productivity per acre, combined with either volume or density (Density = Mass per unit Volume) are basic factors needed to normalize potential feedstocks for comparison (which is often done in terms of energy content).

duction estimates. USDA Extension Services and Land Grant University resources can provide region-specific cultivation or emerging crop land requirement data when more granular data is needed. USFS manages the Forest Inventory and Analysis National Program, which conducts assessments of size, health, production, and utilization of America's forest.

Table B-54. Land Area Required for Feedstock Cultivation Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	No land use
Low	2	Inserted into existing rotational crop (no additive land use)
Moderate	3	STD 0 to STD 1 of identified feedstocks
High	4	STD 1 to STD 2 of identified feedstocks
Highest	5	STD 2 to STD 3 of identified feedstocks

METRIC 3: NET LAND CONVERSION TO CULTIVATION BY TYPE (REGION OR MARKET LEVEL)

Metric 3 is meant to estimate potential land use conversion extent by type within a particular region or market. Given the heterogeneity of land use, this metric includes many of the potential lands available to bring into biomass production using the factors and feedstock specific cultivation requirements explored in metric 2. Metric 3 examines potential land use availability and conversion as part of a feasibility assessment or can be extended into the future through the use of scenarios and models, such as the US Billion-Ton Update estimates generated with the POLYSYS economic model.

This metric captures the original land use being converted to feedstock production. Knowing the acres converted by type is needed not only to satisfy statutory definitions, such as EISA Section 201, but also to generate sufficient fidelity to calculate other metrics that utilize land use conversion as an intermediate factor. For example, carbon storage and release depends greatly upon the land use cover type and its management regime so the amortized life-cycle GHG emissions resulting from such a conversion is needed to calculate that indicator. Certain types of DLUC may also inform the cost calculus needed to inform feedstock production market strategies and provide inputs to bound cost models looking at economic viability. Furthermore, some land use types or displaced crops are likely to raise public concerns over issues such as food security or habitat conversion.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA NASS (www.nass.usda.gov/Data_and_Statistics/index.asp; nassgeodata.gmu.edu/CropScape/ and www.nass.usda.gov/Charts_and_Maps/index.asp)

- ◆ USDA Census of Agriculture (www.agcensus.usda.gov/index.php)
- ◆ USDA NRCS National Resources Inventory (NRI)
(www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/dma/?&cid=nrcs143_014196)
- ◆ USDA NRCS Geospatial Data Gateway (GDG) (datagateway.nrcs.usda.gov/)
- ◆ USGS Land Cover Institute (landcover.usgs.gov/landcoverdata.php)
- ◆ US DOE, US Billion-Ton Update (www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf)
- ◆ US DOE, Bioenergy Knowledge Discovery Framework (KDF)
(<https://www.bioenergykdf.net/>).
- ◆ In addition to the previously discussed NASS data resources, the USDA Census of Agriculture is the flagship reference on agricultural operations, crop production, and lands use. It is updated every 5 years (last iteration was 2007) and includes the baseline land use types, many of which are covered under this metric. NRCS NRI and GDG data resources can be leveraged for the land use analysis.
- ◆ Additional land cover data is available from USGS Land Cover Institute. Scenario and economic modeling planning applications should reference the US Billion-Ton Update.

Table B-55. Net Land Conversion to Cultivation Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	No net land use conversion
Low	2	Inserted into existing rotational crop (no additive land use)
Moderate	3	<5% direct conversion of an existing land use type to feed-stock production
High	4	5-10% direct conversion of an existing land use type to feedstock production
Highest	5	>10% direct conversion of an existing land use type to feed-stock production

METRIC 4: LAND MANAGED UNDER CONSERVATION PRACTICES AND BMPs (REGION OR MARKET LEVEL)

Metric 4's purpose is to assess the use and extent of conservation practices applied to lands producing biofuel feedstock. Basic data needed are the acres of feedstock production land and the subset of acres managed using conservation

practices, BMPs, or sustainable agriculture certifications. The data source availability for calculating this metric will greatly depend upon the scale of analysis (region, market, etc.) and whether NRCS and state agriculture offices maintain such statistics.

- ◆ USDA NRCS National Conservation Practice Standards
(www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/references/?&cid=nrcsdev11_001020)
- ◆ USDA Conservation Effects Assessment Project (CEAP)
(www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap)
- ◆ USDA NRCS Conservation Technical Assistance (CTA)
(www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/cta)
- ◆ USDA NRCS Forestry (www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/forestry)
- ◆ USFS, Sustainable Resource Management (www.fs.fed.us/sustained/msie4.html).

NRCS provides national minimum requirements for conservation, but state requirements may prescribe more stringent and/or comprehensive activities. While these federal or state standards set the floor, this metric also seeks to include and quantify BMP or sustainable agriculture certified acreage.

Table B-56. Land Managed under Conservation Practices and BMP Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	99% land managed for conservation or with BMPs
Low	2	90–<100% land managed for conservation or with BMPs
Moderate	3	70–<90% land managed for conservation or with BMPs
High	4	50–<70% land managed for conservation or with BMPs
Highest	5	<50% land managed for conservation or with BMPs

GENERAL CONSIDERATIONS, ASSUMPTIONS, AND UNCERTAINTIES

The resources and tools listed for each metric are not comprehensive, and additional data sources may be required to strengthen the analysis of this indicator. For example, the Census of Agriculture is conducted at 5-year intervals and may need to be supplemented with additional figures to quantify annual changes in land-use and biofuel feedstock production. In particular, metrics 3 and 4 may require regional- and county-level data and analysis. Projections based upon project plans may require scenarios and modeling to understand the extent and scale of

land use conversion to proactively assess potential consequences. However, such projections also introduce modeling uncertainties as well as require careful analysis boundaries going from attributional to consequential LCAs.

Resources, SMEs, and Capabilities

KEYSTONE RESOURCES

Campbell, J.E. and E. Block, Land-Use and Alternative Bioenergy Pathways for Waste Biomass, 2010, *Journal of Environmental Science and Technology*, 44:8665-8669

Dale, V.H., Efroymsen, R.A., and Kline, K.L., The land use–climate change–energy nexus, *Landscape Ecology*, 26:755–773, 2011, www.ornl.gov/sci/ees/cbes/Publications/Dale%20et%20al%202011%20LU%20CC%20E%20Nexus.pdf

Dale, V.H., Keith L. Kline, Lynn L. Wright, Robert D. Perlack, Mark Downing, and Robin L. Graham, Interactions Among Bioenergy Feedstock Choices, Land-scape Dynamics, and Land Use, *Journal of Ecological Applications*, 21(4), 2011: 1039–1054

GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf

IPCC, *Special report, Land Use, Land-Use Change, and Forestry*, 2000, ISBN: 92-9169-114-3

US DOE. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. ORNL, Oak Ridge, TN. 227p. www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

US DOE, USDA. April 2009. Sustainability of Biofuels: Future Research Opportunities, *Report from the October 2008 Workshop*, DOE/SC-0114

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References

- Campbell, J.E. and E. Block, *Land-Use and Alternative Bioenergy Pathways for Waste Biomass*, 2010, *Journal of Environmental Science and Technology*, 44:8665-8669.
- Dale, V.H., Efroymsen, R.A., and Kline, K.L., The land use–climate change–energy nexus, *Landscape Ecology*, 26:755–773, 2011, www.ornl.gov/sci/ees/cbes/Publications/Dale%20et%20al%202011%20LU%20CC%20E%20Nexus.pdf.
- Dale, V.H., Efroymsen, R.A., and Kline, K.L., Using a Broad-scale Perspective to Address Changes, *Ecosystem Management*, www.ornl.gov/sci/ees/cbes/Publications/The%20Climate-Energy%20Nexus%20P52-55.pdf.
- Dale, V.H., Keith L. Kline, Lynn L. Wright, Robert D. Perlack, Mark Downing, and Robin L. Graham, *Interactions Among Bioenergy Feedstock Choices, Landscape Dynamics, and Land Use*, *Journal of Ecological Applications*, 21(4), 2011: 1039-1054.
- Dale, V. H., R. Lowrance, P. Mulholland, and G. Phillip Robertson, Bioenergy sustainability at the regional scale. *Ecology and Society* 15(4): 23, 2010, www.ecologyandsociety.org/vol15/iss4/art23/ and www.ornl.gov/sci/ees/cbes/Collaborations/USDA/In%20press%20Biofuels_sustainability%20August%202010.pdf.
- Firbank L.G., Assessing the Ecological Impacts of Bioenergy Projects, *BioEnergy Research*, Volume 1, Number 1, 12-19, www.springerlink.com/content/r5668x542208h473/.
- GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.
- Gentry, B., Casey Pickett, and Livia DeMarchis, *Land Conservation and Energy Infrastructure: Threats and Opportunities*, 2011, environment.research.yale.edu/publication-series/5976.
- IPCC, *Special Report, Land Use, Land-Use Change, and Forestry*, 2000, www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf.
- USDA, *Census of Agriculture*, 2007, www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/.
- USDA, NCRS, *Soil and Water Resources Conservation Act (RCA)*, www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/rca/?&cid=nrcs143_008206.

US DOE. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. ORNL, Oak Ridge, TN. 227p. www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf and <https://www.bioenergykdf.net/models/store>.

US DOE, KDF, Land Use Resources, 2012, <https://www.bioenergykdf.net/category/content-categories/feedstock-production/literature/land-use-impacts>.

Soil Quantity

Pillar	Environmental
Criteria	Soil
Indicator	Soil Quantity

Aside from photosynthetic algal systems, the majority of biofuel feedstocks are agricultural and forestry crops, byproducts, or wastes that rely upon soil as a growth media and/or nutrient delivery system.⁸² Soil and its organic components are rebuilt over time, but are a finite resource in terms of human timescale. As such, soil effectively is a non-renewable resource, and its loss during the cultivation of biomass is a potential hazard to supply chain sustainability.

Soil loss or erosion is the breakdown, transport, and relocation of soils by gravity, water, or wind. Erosion rates are a combination of natural factors, such as soil erodibility, surface roughness, and climate. However, certain crop types, cropping systems, and tillage practices can greatly accelerate or reduce erosion rates. For example, over the last 30 years in the United States, erosion rates have been steadily declining from 7.3 tons to 4.8 tons per acre per year due to the adoption of improved tillage and cropping practices.⁸³

Despite this, soil quantity is still considered an economic concern for US agriculture and poses numerous environmental challenges. Erosion, especially of fertile topsoil, has on-site impacts to soil quality and thus to crop productivity. Soil quantity is a direct determinant of productivity. Soil quantity, quality,⁸⁴ and productivity are integrally linked. As such, soil quantity and its conservation is a key prerequisite for both as the lack of topsoil makes soil health and productivity largely irrelevant. Furthermore, soil carried off site can generate local and regional impacts on water quality, air quality, and land use.



⁸² Photosynthetic algal feedstock products produced via aquaculture do not require soil as a growth media. Heterotrophic algal systems (dark reaction fermentation) produce products in closed bioreactors but rely on external agricultural sugar feedstocks that still require soil growth media. As such, such systems inherently require quantities of soil inputs.

⁸³ USDA, NRCS, 2007 *National Resource Inventory*, December 2009, <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri>.

⁸⁴ USDA, NRCS, *Soil Quality/Soil Health Concepts*, <http://soils.usda.gov/sqi/concepts/concepts.html>.

Given this, soil quantity is a keystone indicator that influences and directly impacts numerous indicator areas. It can likewise have secondary impacts that are just as critical in terms of economic viability, public health, and food security.

RELEVANCE AND RATIONALE

Soil quantity management will lead to more sustainable and more economical cultivation of bioenergy feedstocks. Assessing the overall sustainability of biofuels through the perspective of this indicator may favor bioenergy feedstocks from sources such as biomass waste and perennial grasses that have little additive contribution to problems associated with soil erosion. Some cover crops, that reduce erosion, are being considered as both bioenergy feedstocks and soil conservation solutions when integrated with cultivation of conventional food crops.

Numerous erosion control programs and incentives have been introduced and mandate erosion control, particularly on highly erodible lands (HEL), as defined by the erodibility index in the National Food Security Act Manual. In the context of biomass cultivation, Table B-57 highlights statutes and policies where soil quality has general or direct relevance.

Table B-57. Soil Quantity Statutory, USG Policy, and DoD Policy Relevance

	Statutory and regulatory relevance		
	General relevance	Direct relevance	Proposes metric
Biomass Research and Development Act of 2000		Yes	
2002 Farm Bill	Yes		
Energy Policy Act of 2005		Yes	
EISA of 2007		Yes	
Food, Conservation, and Energy Act of 2008		Yes	
National Environmental Protection Act of 1970	Yes		

Interest in the soil quantity, erosion, and conservation is widespread beyond federal regulatory drivers. Indicators relating to overall soil quality (including soil quantity) appear in several sustainability frameworks, approaches, and industry standards (Table B-58).

Table B-58. Soil Quantity in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
USDA Biofuel Sustainability Assessment Framework	Yes	
CAAFI Environmental Working Group	Yes	Yes
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Soil quantity metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for quantitative comparisons among drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the erosion hazard posed by a particular feedstock crop and cultivation system; and, second, quantification of the location specific sensitivity to erosion.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Average soil erosion loss for cropping system, tons/acre/year
- ◆ Metric 2: Relative erosion hazard of crop sequence, range of 0–244.

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 3: Soil loss tolerance (T-factor) of local soils, tons/acre/year
 - ◆ T-factor is an estimate of the maximum average annual rate of soil erosion by wind and/or water possible without affecting productivity
- ◆ Metric 4: Soil erodibility (K-factor) of local soils, range of 0.02–0.69
 - ◆ K-factor is the soil susceptibility to sheet and rill erosion⁸⁵ by water
- ◆ Metric 5: Wind erodibility group of local soils, range of 1–8
 - ◆ Wind erodibility group defines soil properties indicative of their susceptibility to wind erosion.

⁸⁵ Sheet erosion is the transport of soil particles by surface runoff that is flowing downhill in sheets. Rill erosion is the development of small, ephemeral concentrated flow paths on hillslopes that gouge out surface soils. Sheet and rill erosion are the first stages in water erosion.

Risk Reduction (Mitigation Metrics)

- ◆ Metric 6: Soil managed under conservation plans and BMPs, acres/total acres or percentage.

Applicability of soil quantity has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-59 summarizes these applicability findings.

Table B-46. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Average soil erosion loss for cropping system	Yes	N/A	N/A	N/A	N/A
Metric 2: Relative erosion hazard of crop sequence	Yes	N/A	N/A	N/A	N/A
Metric 3: Soil loss tolerance (T-factor) of local soils	Yes	N/A	N/A	N/A	N/A
Metric 4: Soil erodibility (K-factor) of local soils	Yes	N/A	N/A	N/A	N/A
Metric 5: Wind erodibility group of local soils	Yes	N/A	N/A	N/A	N/A
Metric 7: Soil managed under conservation plans and BMPs	Yes	N/A	N/A	N/A	N/A

Given the soil quantity metrics focus on stage 1 cultivation activities, feedstocks derived from wastes would not likely require the application of these metrics.

MEASUREMENT AND ANALYSIS APPROACH

Numerous factors determine the quantity of soil eroded from an individual agricultural plot. The Revised Universal Soil Loss Equation (RUSLE) estimates soil loss, sediment yield, and sediment characteristics from sheet and rill erosion using factors that quantify the effects of climate, erodibility, topography, and land use.⁸⁶ Similar to earlier versions of this equation (Universal Soil Loss Equation [USLE]),

⁸⁶ USDA, ARS, User's Guide Revised Universal Soil Loss Equation, Version 2, January 2003, http://fargo.nserl.purdue.edu/rusle2_dataweb/userguide/RUSLE2-2-3-03.pdf.

RUSLE1), RUSLE2 estimates average annual soil loss, expressed in tons per acre per year on each day given by:

$$a_i = r_i k_i l_i S_i c_i p_i^{87}$$

where: a_i = average annual soil loss, r_i = erosivity factor, k_i = soil erodibility factor, l_i = soil length factor, S_i = slope steepness factor, c_i = cover-management factor, and p_i = supporting practices factor.⁸⁸

The RUSLE2 equation and associated database are widely accepted as a means to estimate soil loss from sheet and rill erosion. However, use of both the equation and database requires specific knowledge and can be time intensive. Given the complexity of the RUSLE2 equation and database, the following metric approaches have been developed as a representative, but simpler means to estimate soil erosion hazard, consequence, and mitigation of biomass cultivation. Not all factors of the RUSLE2 equation are represented within the proposed screening metrics and are certainly not a replacement for pathway specific analysis. The RUSLE2 equation/database should be utilized when more detailed soil erosion potential assessments are required.

Metric 1: Average Soil Erosion Loss for Cropping System

Metric 1 focuses on the quantity of soil lost due to erosion for various cropping and tillage systems. This metric is greatly impacted by the soil type, crop, cropping system, and management practices used.

Key measurements, databases, and approaches for calculating Metric 1 include:

- ◆ Soil erosion losses reported in Langdate et al., “Cover crop effects on soil erosion by wind and water,” *Cover Crops for Clean Water*, ed. W.L. Hargrove, (Soil and Water Conservation Society 1991).

Table B-60 provides erosion loss rates for various cropping and tillage systems.

Table B-60. Example Soil Erosion Loss Rates^a

Summer crop	Winter cover crop	Tillage system	Soil loss (tons/acre/year)	Location
Soybean	No cover	No-till	1.09	Missouri
	Chickweed	No-till	0.19	
	Canada bluegrass	No-till	0.08	
	Downy brome	No-till	0.10	

⁸⁷ Lower case letters are used to denote daily variables in comparison to the upper case letters used in the USLE and RUSLE1 that denote average annual values.

⁸⁸ USDA, ARS, User's Guide Revised Universal Soil Loss Equation, Version 2, January 2003, http://fargo.nserl.purdue.edu/rusle2_dataweb/userguide/RUSLE2-2-3-03.pdf.

Table B-60. Example Soil Erosion Loss Rates^a

Summer crop	Winter cover crop	Tillage system	Soil loss (tons/acre/year)	Location
Soybean	No cover	Conventional	3.34 ^b	Tennessee
	Wheat	Conventional	0.75 ^b	
	No cover	No-till	0.05 ^b	
	Wheat	No-till	0.04 ^b	
Soybean	No cover	Conventional	4.04	Kentucky
	Wheat	Conventional	0.51	
	No cover	No-till	0.19	
	Wheat	No-till	0.12	
Cotton ^c	No cover	No-till	8.93	Mississippi
	Weeds	No-till	8.21	
	Hairy vetch	No-till	1.03 ^c	
Cotton ^d	No cover	Conventional	0.45 ^f	Mississippi
	Weeds	No-till	0.58 ^f	
	Hairy vetch/wheat	No-till	0.40	
Cotton ^e	No cover	Conventional	33.35	Mississippi
	Weeds	Conventional	32.90	
	Hairy vetch/wheat	Conventional	9.11	

^a Soil erosion losses are for Alfisols in systems including cover crops compared to no cover crop systems. Langdate et al., "Cover crop effects on soil erosion by wind and water," *Cover Crops for Clean Water*, ed. W.L. Hargrove, (Soil and Water Conservation Society 1991).

^b Mean soil loss associated with soybean cropping/tillage systems during April/July study periods. Mean of 17 storms of high intensity that occurred in **1980–1986** that included natural storms and simulated rainfall.

^c Following reduced tilled soybean.

^d Following no-till soybean-wheat double cropped.

^e Following 11 years of conventional tilled corn/soybean.

^f One year of data.

Crop-specific soil loss rates vary greatly throughout the country as they depend upon environmental factors, such as soil, precipitation, slope, etc. Therefore, it is important to identify average soil losses representative for the associated region and locality as such information is available. Average soil loss rates for specific crops are available from studies conducted within or from a neighboring region.

Once appropriate average soil loss rates are identified, this metric is used for evaluating the level of soil quantity hazard. Table B-61 shows hazard thresholds based on the soil loss rates provided in Table B-60. However, these threshold levels should be revised with local average soil loss rates should they be available.

Table B-61. Soil Erosion Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<0 tons/acre/year ⁸⁹
Low	2	0–1 tons/acre/year
Moderate	3	1–5 tons/acre/year
High	4	5–10 tons/acre/year
Highest	5	>10 tons/acre/year

Metric 2: Relative Erosion Hazard of Crop Sequence

Metric 2 reinforces that of Metric 1 and focuses on the relative erosion hazard of various cropping sequences. This metric is similar in that it can be greatly impacted by the soil type, crop, cropping system, and management practices used.

Key measurements, databases, and approaches for calculating Metric 2 include:

- ◆ Relative erosion hazards reported in Al-Kaisi, Mahdi, “Soil erosion: An agricultural production challenge,” *Integrated Crop Management News*, July 24, 2000.

Table B-62 provides soil erosion loss rates for several cropping sequences.

Table B-62. Relative Erosion Hazards of Selected Crop Sequences (Continuous corn=100)^a

Crop sequence	Relative erosion hazard
Fallow	244
C-Sb	120
C-C-Sb	112
Continuous corn	100
C-C-C-Ox	73
C-C-Ox	68
C-Ox	59
C-C-C-O-M	46
C-C-O-M	32

⁸⁹ <0 tons/acre/year rate reflects a biomass production system that is not only sustainable but can actually be restorative of soil. This is a core objective for realizing sustainable agriculture and biomass production moving forward. Such cultivation systems would generate, trap, and add to topsoil, rather than removing it via erosion mechanisms.

Table B-62. Relative Erosion Hazards of Selected Crop Sequences (Continuous corn=100)^a

Crop sequence	Relative erosion hazard
C-C-O-M-M	27
C-C-O-M-M-M	22
C-O-M	17
C-O-M-M	12
C-O-M-M-M	10
C-O-M-M-M	9
Continuous clover	0

^a Al-Kaisi, Mahdi, "Soil erosion: An agricultural production challenge," *Integrated Crop Management News*, July 24, 2000, <http://www.ipm.iastate.edu/ipm/icm/2000/7-24-2000/erosion.html>.

^b C-Corn; Sb-Soybeans; O-Oats; Ox-Oats with green manure crop; M-Meadow.

The relative erosion hazards provided are representative of national averages. As such, studies of relative erosion hazards should be used when such studies are available at the regional or local level. Once the appropriate relative erosion hazards are identified, these values are used to evaluate the likelihood of soil quantity impact. Table B-63 defines the hazard thresholds based on the relative erosion rates provided in Table B-62.

Table B-63. Relative Soil Erosion Hazard Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	0–1 (continuous cover)
Low	2	1–65
Moderate	3	65–130
High	4	130–200
Highest	5	>200 (tilled and fallow)

Metric 3: Soil Loss Tolerance (T-factor) of Local Soils

As a consequence component, Metric 3's focus is on the soil loss tolerance, known as the T-factor, of the local soils. The T-factor is an estimate, in tons per acre per year, of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. Soil loss tolerance values range from 1 to 5 tons/acre/year. For example, shallow and fragile soils that cannot be easily reclaimed after serious erosion are assigned

low soil loss tolerances values. T-factor values consider the damages caused by erosion and the benefits of soil conservation. However, note that soil loss tolerance values include an economic element by considering the availability of reasonable and profitable erosion control technology.⁹⁰

Key measurements, databases, and tools for calculating Metric 3-5 include:

- ◆ USDA NRCS Web Soil Survey (WSS)
(<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>).

Once crop cultivation location(s) is identified, NRCS's WSS should be used to identify the T-factor for local soils. When accessing the WSS, the area of interest (AOI) is defined and used to access the "Soil Data Explorer" tab. Access the "Soil Properties and Qualities" tab and select T-factor under the soil erosion factors. If more than one soil is included in your AOI, use a weighted average based on all T-factors in the AOI and the amount of land associated with each soil type.

Apply these findings against the thresholds presented in Table B-64 to determine the resultant consequence rating.

Table B-64. Soil Loss Tolerance (T-Factor) Thresholds for Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Lowest	1	5 tons/acre/year
Low	2	4 tons/acre/year
Moderate	3	3 tons/acre/year
High	4	2 tons/acre/year
Highest	5	1 tons/acre/year

Metric 4: Soil Erodibility (K-factor) of Local Soils

Metric 4 reflects the sensitivity of the local soils to water erodibility and is known as the K-factor. Soil erodibility, K-factor defines the susceptibility of a soil to sheet and rill erosion by water. It is one of six factors used by the USLE and the RUSLE to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. These estimates are primarily based on percentage of silt, sand, and organic matter as well as on the soil structure and saturated hydraulic conductivity (Ksat). K-values range from 0.02 to 0.69, with higher values indicating a higher susceptibility of the soil to sheet and rill erosion by water.⁹¹

Similar to Metric 3, USDA NRCS's WSS is accessed and used to identify the soil erodibility (K- factor) of local soils. If more than one soil is included in the AOI,

⁹⁰ USDA, NRCS, WSS, <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.

⁹¹ Ibid.

weighted average should be used, based on all K-factors in the AOI and the amount of land associated with each soil type. Apply these results using the thresholds presented in Table B-65 and determine the resulting consequence rating.

Table B-65. Soil Erodibility (K-Factor) Thresholds for Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Lowest	1	0.02–0.15
Low	2	0.16–0.29
Moderate	3	0.30–0.42
High	4	0.43–0.56
Highest	5	0.57–0.69

Metric 5: Wind Erodibility Group of Local Soils

Metric 5 reflects the susceptibility of soil to wind erosion within cultivated areas. The soils assigned to Group 1 are the most susceptible to wind erosion, and those assigned to Group 8 are the least susceptible.

Similar to Metrics 4 and 5, the USDA NRCS's WSS should be used to identify the wind erosion group of local soils. Again, if more than one soil is included in the AOI, weighted average should be used, based on all wind erosion groups included and the amount of land associated with each soil type. Apply these results using the thresholds presented in Table B-66 and determine the resulting consequence rating.

Table B-66. Wind Erodibility Group Thresholds for Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Lowest	1	1
Low	2	2–3
Moderate	3	4–5
High	4	6–7
Highest	5	8

Metric 6: Soil Managed Under Conservation Plans and BMPs

An integrated approach to soil management emphasizes the maintenance of soil structure, protection of soil surface, and prevention of nutrient loss. Integrated

conservation plans and BMPs are necessary to effectively reduce soil quantity risk and to improve crop productivity. As such, Metric 7 assesses the use of soil conservation plans and BMPs when applied to lands used to produce biofuel feedstocks. Data needed for this metric are the acres of feedstock cultivation land and the portion of that land managed using conservation plans, BMPs, or related sustainable agriculture certifications. The data source availability for calculating this metric will vary based upon NRCS, state, and local agricultural extension offices maintaining such statistics or may require self-reporting by producers.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA NRCS National Conservation Practice Standards (http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/references/?&cid=nrcsdev11_001020)
- ◆ USDA NRCS Soil Data Mart (<http://soildatamart.nrcs.usda.gov/>)
- ◆ USDA NRCS Conservation Technical Assistance (<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/cta>).

NRCS defines the national minimum requirements for conservation, but state requirements may prescribe more stringent and/or comprehensive activities. While these federal or state standards set the floor, this metric includes and quantify BMP or sustainable agriculture certified acreage.

Table B-67. Soil Conservation Plans, Management, and BMP Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	100% soil managed for conservation or with BMPs
Low	2	90% to <100% soil managed for conservation or with BMPs
Moderate	3	70% to <90% soil managed for conservation or with BMPs
High	4	50% to <70% soil managed for conservation or with BMPs
Highest	5	<50% soil managed for conservation or with BMPs

General Considerations, Assumptions, and Uncertainties

The listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and gaps associated with data availability and reporting will likely arise, particularly for emerging energy crops.

The proposed metrics were developed as a representative but simple means to estimate soil erosion, consequences, and mitigations of biomass cultivation and its respective biofuel production pathways. For example, factors, such as slope length and steepness, are not included as metrics because of data requirements

involved with each agricultural field under consideration. If more comprehensive soil quantity assessments are needed, the RUSLE2 equation/database should be utilized on a case by case basis.

RESOURCES, SMEs, AND CAPABILITIES

Keystone Resources

Council on Sustainable Biomass, *Standard for Sustainable Production of Biomass*, Version 1.0, June 6, 2012, www.csbp.org/Portals/0/Documents/CSBP%20Standard%20For%20Sustainable%20Production%20of%20Agricultural%20Biomass%2006122012_1.pdf

GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, p. 57, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

USDA ARS, *Revised Universal Soil Loss Equation 2—Overview of RUSLE 2*, April 2010, fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

USDA, NRCS, *2007 National Resource Inventory*, December 2009

USDA, NRCS, WSS, websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Identified SMEs and Organizations

Dave Lightle, USDA NRCS

Linda Scheffe, USDA NRCS

Supplementary Supporting Capabilities

RUSLE2 was not proposed in the metric descriptions above due to its complexity, SME involvement, and time resource required. However, RUSLE2 is the current standard for these types of analysis. As such, it is a potential option for deeper analysis at the regional and local levels. For more detail and background, refer to the RUSLE2 website (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm).

REFERENCES

Al-Kaisi, Mahdi, “Soil erosion: An agricultural production challenge,” *Integrated Crop Management News*, July 24, 2000, <http://www.ipm.iastate.edu/ipm/icm/2000/7-24-2000/erosion.html>.

- Iowa State University Extension, *Soil erosion and the Iowa Soil 2000 Program*, Gerald Miller et al., August 1988, <http://www.ipm.iastate.edu/ipm/icm/2000/7-24-2000/erosion.html>.
- Kelsey, K., and T. Johnson, *Determining Cover Management Values (C Factors) for Surface Cover Best Management Practices (BMPs)*, 2002, [http://www.americanexcelsior.com/erosioncontrol/library/Technical%20Papers/\(2003%20IECA\)%20Determining...%20\(BMPs\).pdf](http://www.americanexcelsior.com/erosioncontrol/library/Technical%20Papers/(2003%20IECA)%20Determining...%20(BMPs).pdf).
- Langdale G.W., R. L. Blevins, D. L. Karlen, D. K. McCool, M. A. Nearing, E. L. Skidmore, A. W. Thomas, D. D. Tyler, and J. R. Williams, "Cover crop effects on soil erosion by wind and water," *Cover Crops for Clean Water*, ed. W.L. Hargrove, (Soil and Water Conservation Society 1991).
- USDA ARS, *Revised Universal Soil Loss Equation 2—Overview of RUSLE 2*, April 2010, http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.
- USDA ARS, *User's Guide, Revised Universal Soil Loss Equation, Version 2*, January 2003, http://fargo.nserl.purdue.edu/rusle2_dataweb/userguide/RUSLE2-2-3-03.pdf.
- USDA, NRCS, *2007 National Resource Inventory*, December 2009, <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri>.
- USDA, NRCS, *Soil Quality/Soil Health Concepts*, <http://soils.usda.gov/sqi/concepts/concepts.html>, accessed October 2012.
- USDA, NRCS, WSS, <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.

Soil Quality

Pillar	Environmental
Criteria	Soil
Indicator	Soil Quality

The USDA NRCS defines soil quality as “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.”⁹² Soil quality is generally how well soil performs the functions necessary for its intended use.⁹³

Some key soil functions include:

- ◆ sustaining biological diversity, activity, and productivity;
- ◆ regulating water and solute flow;
- ◆ filtering, buffering, and degrading organic and inorganic materials;
- ◆ storing and cycling nutrients and carbon; and
- ◆ providing physical stability and support.⁹⁴

Soil quality interacts with and influences several indicators. Soil characteristics determine nutrient cycling and release, erosion rates, and runoff, which greatly influence the water quality in lakes, rivers, and estuaries. Soil organic carbon (SOC) and land use change are the second largest drivers of direct GHG emissions behind energy use. Soil quality is an important driver of land productivity and sustaining both soil quality and productivity which helps determine a pathway’s economic viability. In short, good soil quality not only results in environmental benefits but in supporting the sustained economic viability of a biofuel enterprise into the future.⁹⁵



⁹² USDA, NRCS, *Soil Quality/Soil Health Concepts*, <http://soils.usda.gov/sqi/concepts/concepts.html>.

⁹³ USDA, NRCS, *Soil Quality/Soil Health*, <http://soils.usda.gov/sqi/>.

⁹⁴ USDA, NRCS, *Soil Quality Indicator Guide Sheet*, September 2009, <http://soils.usda.gov/sqi/assessment/assessment.html>.

⁹⁵ Soil Quality for Environmental Health, *Value of Soil*, <http://soilquality.org/basics/value.html>.

Soil quality is a key indicator in biomass cultivation as it determines the productivity of bioenergy crops, affects the broader ecosystem, and plays an important role in maintaining the land's productive capacity for future generations.⁹⁶

The three main categories of soil properties include chemical, physical, and biological. Organic matter, or more specifically SOC, transcends all three indicator categories and has the most widely recognized influence on soil quality. Organic matter is tied to all soil functions. It affects other indicators, such as aggregate stability (physical), nutrient retention and availability (chemical), and nutrient cycling (biological); and is itself an indicator of soil quality.⁹⁷ Other key characteristics of soil quality generally include soil erosion, nutrients, salinization, and soil compaction. As soil erosion and nutrients are separate indicators, they are not addressed here. Soil quality attributes addressed under this indicator include soil organic matter and SOC, soil salinization, and soil compaction.

RELEVANCE AND RATIONALE

Effective soil quality analysis and management supports the sustainable and economical cultivation of bioenergy feedstocks so it is a significant consideration. Table B-68 highlights statutes where soil quality has general or direct relevance. It is notable that almost all of the energy, agriculture, and bioenergy related statutory mandates reviewed have directly relevant provisions.

Table B-68. Soil Quality Statutory Relevance

	General relevance	Direct relevance
<i>Statutory and Regulatory Relevance</i>		
Biomass Research and Development Act of 2000		Yes
Energy Policy Act of 2005		Yes
EISA of 2007		Yes
Food, Conservation, and Energy Act of 2008		Yes
National Environmental Protection Act of 1970	Yes	

Interest in the quality of soil is widespread across biofuel sustainability frameworks, approaches, and industry standards. Table B-69 illustrates that soil quality indicators appear in virtually all frameworks and standards with some even proposing specific metrics.

⁹⁶ McBride, Allen C., et al., "Indicators to support environmental sustainability of bioenergy systems," *Ecological Indicators* 11 (2011), p. 1277–1289.

⁹⁷ Soil Quality for Environmental Health, *Soil Quality Indicators: Measures of Soil Functional State*, <http://soilquality.org/indicators.html>.

Table B-69 Soil Quality in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
DOE Biomass Program, Sustainability Platform	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	Yes
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	
GBEP	Yes	
ISO 14025 Product Category Rules	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Soil quality metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for meaningful comparisons among drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the soil quality hazard posed by a particular feedstock crop and cultivation system; and, second, quantification of the location's specific sensitivities and impacts, particularly where soil quality is already poor.

Pathway Characteristics (Likelihood Metrics⁹⁸)

- ◆ Metric 1: Net change in SOC, milligrams (mg)/hectare (ha)/30 centimeters (cm)
- ◆ Metric 2: Cropping system influence on soil compaction
- ◆ Metric 3: Soil salinization potential (based on irrigation water requirements of crops), acre-feet applied/acre

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 4: Soil organic matter content, percentage, by weight, of the soil material less than 2 millimeters in diameter
- ◆ Metric 5: Bulk density, grams/centimeter cubed (g/cm³)
- ◆ Metric 6: Soil salinity, electrical conductivity (mmho/cm) and sodium adsorption ratio (SAR)²

⁹⁸ Other soil quality indicators were considered, such as total nitrogen and extractable phosphorus. These are all significant parameters of soil quality, but because both nitrogen and phosphorus are covered in both the Nutrients and Water Quality Indicator Sheets, they are not covered under soil quality.

- ◆ Metric 7: Irrigation water withdrawals, million gallons (gal)/day

Risk Reduction (Mitigation Metrics)

- ◆ Metric 8: BMPs implemented, Yes/No

The applicability of soil quality metrics has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-70 summarizes these findings.

Table B-70. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Net change in SOC	Yes	No	No	No	No
Metric 2: Cropping system influence on soil compaction	Yes	No	No	No	No
Metric 3: Soil salinization potential	Yes	No	No	No	No
Metric 4: Soil organic matter content	Yes	No	No	No	No
Metric 5: Bulk density	Yes	No	No	No	No
Metric 6: Soil salinity	Yes	No	No	No	No
Metric 7: Irrigation water withdrawals	Yes	No	No	No	No
Metric 8: BMPs implemented	Yes	No	No	No	No

MEASUREMENT AND ANALYSIS APPROACH

Metrics 1, 2, and 3 are intended to assess the soil quality hazards from particular feedstock crops and cultivation systems. Metrics 4 through 7 focus on consequence metrics understanding the regional or local susceptibility to soil quality degradation and impacts. Finally, Metric 8 focuses on the application of BMPs and its mitigation of the raw hazard rating and risk score.

Metric 1: Net Change in SOC

Metric 1 reflects the estimated net change in SOC under biofuel feedstocks. SOC is the total organic carbon of a soil, excluding carbon from undecayed plants and animal residues. SOC is major component of soil organic matter (SOM). The amount of SOM directly affects several aspects of soil function so SOC is commonly used to measure soils organic matter content in and as an indicator to

assess soil quality and productivity.⁹⁹ SOC is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization.¹⁰⁰ This metric assesses crop cultivation changes to SOC.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ Estimated net change in SOC in the top 30 centimeters (cm) of soil under biofuel crops reported in Anderson-Teixeira et al., “Changes in soil organic carbon under biofuel crops”, *GCB Bioenergy*, 2009, Volume 1:75–96 (<http://www.life.illinois.edu/delucia/publications.htm>).

Anderson-Teixeira et al. analyzed and provides estimates of SOC change following conversion of natural or agricultural land to five biofuel cropping systems.¹⁰¹ In evaluating additional feedstock crops, the estimated net change in SOC should be compared to its or its closest relative to validate against, the results found in Anderson-Teixeira et al.

Once determined, Table B-71 defines hazard thresholds to evaluate the likelihood associated with estimated SOC changes. These thresholds are based upon the natural statistical breaks identified in Figure B-70 of Anderson-Teixeira et al. 2009.

Table B-71. Estimated SOC Change Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	>10 mg/ha/30 cm
Low	2	5–10 mg/ha/30 cm
Moderate	3	5– -5 mg/ha/30 cm
High	4	-5– -10 mg/ha/30 cm
Highest	5	<-10 mg/ha/30 cm

Metric 2: Cropping System Influence on Soil Compaction

Metric 2 is the biofuel feedstock cropping system influence on the soils compaction. Soil compaction is an issue because it reduces the soil pore volume, resulting in less space for air and water in the soil. Rainwater can easily penetrate

⁹⁹ GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

¹⁰⁰ Soil Quality for Environmental Health, *Total Organic Carbon*, http://soilquality.org/indicators/total_organic_carbon.html.

¹⁰¹ Anderson-Teixeira et al., “Changes in soil organic carbon under biofuel crops,” *GCB Bioenergy*, 2009, Volume 1:75–96 doi: 10.1111/j.1757-1707.2008.01001.x, <http://www.life.illinois.edu/delucia/publications.htm>.

excessively compacted soils and increases the potential for runoff and erosion.¹⁰² Furthermore, excessive soil compaction impedes root growth and, therefore, limits plant root growth and extent. This can decrease the plant's ability to take up nutrients and water.¹⁰³

Key measurements, databases, and tools for calculating Metric 2 include:

- ◆ University of Wisconsin Extension, *Soil Compaction: Causes, Concerns, and Cures*, A3367, Richard Wolkowski & Birl Lowery, 2008 (<http://www.soils.wisc.edu/extension/pubs/A3367.pdf>).
- ◆ State-land grant universities, soil compaction analysis, and resources

According to the University of Wisconsin Extension, the trend toward continuous row crops, instead of crop rotations including solid-seeded/deep-rooted crops such as alfalfa, increases the potential for soil compaction. Perennial alfalfa/grass mixture crops, because of their dense canopies and taproot systems, provide greater support at the soil surface than row crops and create channels deep into the soil that subsequent crops can use. Perennial crops also tend to favor aggregation, where row crops have been shown to have lower aggregate stability.¹⁰⁴

Based on this extension work, Table B-72 defines hazard thresholds to evaluate the likelihood of a biofuel cropping system's influencing soil compaction.

Table B-72. Cropping System Influence on Soil Compaction Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Perennial alfalfa/grass mixture crops
Moderate	3	Crop rotations that include solid-seeded/deep-rooted crops such as alfalfa
Highest	5	Continuous row crops

Metric 3: Soil Salinization Potential (from Irrigation)

Metric 3 reflects the potential of soil salinization to occur under different biofuel feedstock crops based on irrigation water requirements. Salinization is the process

¹⁰² University of Wisconsin Extension, *Soil Compaction: Causes, Concerns, and Cures*, A3367, Richard Wolkowski & Birl Lowery, 2008, <http://www.soils.wisc.edu/extension/pubs/A3367.pdf>.

¹⁰³ University of Minnesota Extension, *Soil Compaction: Causes, Effects and Control*, <http://www.extension.umn.edu/distribution/cropsystems/components/3115s01.html>.

¹⁰⁴ See footnote 102, this appendix.

by which water-soluble salts accumulate in the soil. It is a problem as excess salts hinder the crops growth by limiting their ability to take up water.¹⁰⁵

Irrigation water application is the delivery vehicle for the addition of soluble salts, such as sodium, calcium, magnesium, potassium, sulfate, and chloride dissolved from natural deposits. Evaporation and plant uptake of irrigation water lead to the accumulation of excessive amounts of salts in soils, particularly with in adequate leaching and drainage.¹⁰⁶ Therefore, we are using irrigation water requirements of feedstocks as a proxy to estimate the soil salinization potential.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA, Census of Agriculture, *Farm and Ranch Irrigation Survey*, 2008, Table 28, (http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.php).

Table B-73 provides average irrigation water application rates in 2008 at the national level for various crops.

Table B-73. Estimated Quantities of Irrigation Water Applied in the United States^a

Crop	Acre-feet applied/acre
Corn for grain or seed	1.0
Corn for silage or greenchop	2.1
Sorghum for grain or seed	0.9
Wheat for grain or seed	1.4
Barley for grain or seed	1.5
Soybeans for beans	0.7
Beans, dry edible	1.4
Rice	2.3
Other small grains (oats, rye, etc.)	1.4
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)	2.4
All other hay (dry hay, greenchop, and silage)	1.8
Peanuts for nuts	1.0
All cotton	1.3
Sugarbeets for sugar	2.6
Tobacco, all types	0.4
Land in vegetables	2.0
Sweet corn	1.5

¹⁰⁵ USDA NRCS, *Soil Quality Resource Concerns: Salinization*, January 1998, www.urbanext.illinois.edu/soil/sq_info/saline.pdf.

¹⁰⁶ USDA ARS, *Frequently Asked Questions About Salinity*, <http://www.ars.usda.gov/Aboutus/docs.htm?docid=10201>.

Table B-73. Estimated Quantities of Irrigation Water Applied in the United States^a

Crop	Acre-feet applied/acre
Tomatoes	2.6
Lettuce and romaine	2.9
Potatoes	1.8
All berries	2.2
Land in orchards, vineyards, and nut trees	2.4
All other crops	1.8
Pastureland, all types	1.6

^a 2008 estimated quantities of irrigation water applied in the United States are from USDA, Census of Agriculture, *Farm and Ranch Irrigation Survey*, 2008, Table 28, http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.php.

Table B-73 factors are representative of national averages. However, quantities of irrigation water applied depend on local conditions and, therefore, can vary greatly among states, regions, and localities. As such, state, regional, or local averages should be used to the full extent possible. Average acre-feet of irrigation water applied per acre for select crops are available at the state level for some states in the USDA Census of Agriculture, 2008 *Farm and Ranch Irrigation Survey*. If local and state rates are not available for the feedstock of interest, the national levels provided in Table B-73 can be used but with recognition that these rates may not be representative of the local quantities of irrigation water used for specific crops.

Once appropriate irrigation water application rates are identified, this metric is used to evaluate the potential of soil salinization hazard of a particular feedstock. Table B-74 shows hazard thresholds based on the national irrigation water quantities provided in Table B-73. However, these threshold levels can be revised to considering state or local irrigation water application rates and salt content, as appropriate.

Table B-74. Average Irrigation Water Quantity Thresholds

Likelihood of hazard	Assessed value	Threshold (acre-feet applied per acre)
Lowest	1	<0.9
Low	2	0.9–1.3
Moderate	3	1.4–1.9
High	4	2.0–2.5
Highest	5	>2.5

Metric 4: Soil Organic Matter Content

As a consequence metric, Metric 4 focuses on the organic matter content of local soils. SOM has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.¹⁰⁷ Soils with low organic matter content also tend to be more susceptible to compaction as they do not form strong aggregates.

Key measurements, databases, and tools for calculating Metric 4 includes:

- ◆ USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>).

Once crop cultivation location(s) is identified, NRCS's WSS should be used to identify the SOM. When accessing the WSS, the AOI is defined and used to access the "Soil Data Explorer" tab. Access the "Soil Properties and Qualities" tab and select "Organic Matter" under the "Soil Physical Properties" category. If more than one soil is included in your AOI, use a weighted average based on the organic content of soils in the AOI and the amount of land associated with each soil type.

According to the FAO, most soils contain 2–10 percent organic matter and minerals.¹⁰⁸ Table B-75 presents consequence rating thresholds based on this typical range. Once the organic matter content of local soils is determined, apply these findings against the thresholds presented in Table B-75 to determine the resultant consequence rating.

*Table B-75. Organic Matter Thresholds
for Local Sensitivity*

Consequence of hazard	Assessed value	Threshold
Lowest	1	>8%
Low	2	>6–8%
Moderate	3	>4–6%
High	4	>2–4%
Highest	5	<2%

Metric 5: Bulk Density

As discussed in Metric 2, compaction changes pore space size, distribution, and soil strength. Metric 2 estimates compaction based on the cropping system used; but, the type of soil also impacts its potential for compaction. Bulk density is a

¹⁰⁷ USDA NRCS, WSS, <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.

¹⁰⁸ FAO, *The importance of soil organic matter*, <ftp://ftp.fao.org/agl/agll/docs/sb80e.pdf>.

metric for quantifying local soils susceptibility to compaction. Metric 5 captures the bulk density of local soils to estimate their susceptibility to compaction.

Compaction causes an increased soil bulk density as soil aggregates are pressed closer together, resulting in a greater mass per unit volume. Thus, as the pore space is decreased within a soil, the bulk density is increased. Soils with a higher percentage of clay and silt, which naturally have more pore space, have a lower bulk density than sandier soils.¹⁰⁹

Key measurements, databases, and tools for calculating Metric 5 include:

- ◆ USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>).

Once crop cultivation location(s) is identified, NRCS's WSS should be used to identify the bulk density of local soils. When accessing the WSS, the AOI is defined and used to access the "Soil Data Explorer" tab. Access the "Soil Properties and Qualities" tab and select "Bulk Density" under the "Soil Physical Properties" category. Use either the one-tenth or one-third bar depending on which bulk density information is available in WSS. If more than one soil texture or type is included in your AOI, use a weighted average based on all bulk densities in the AOI and the amount of land associated with each soil texture and type.

Table B-76 defines the consequence rating thresholds for different soil textures based on ideal soil bulk densities for plant growth versus bulk densities that restrict root growth, as described in USDA NRCS's *Soil Quality Indicators: Bulk Density* sheet.¹¹⁰

*Table B-76. Bulk Density Thresholds
for Local Sensitivity By Soil Type^a*

Consequence of hazard	Assessed value	Threshold
Sandy Soil Texture		
Lowest	1	<1.60 g/cm ³
Moderate	3	1.60–1.80 g/cm ³
Highest	5	>1.80 g/cm ³
Silty Soil Texture		
Lowest	1	<1.40 g/cm ³
Moderate	3	1.40–1.65 g/cm ³
Highest	5	>1.65 g/cm ³

¹⁰⁹ University of Minnesota Extension, *Soil Compaction: Causes, Effects and Control*, <http://www.extension.umn.edu/distribution/cropsystems/components/3115s01.html>.

¹¹⁰ USDA NRCS, *Soil Quality Indicators: Bulk Density*, June 2008, <http://soils.usda.gov/sqi/assessment/assessment.html>.

*Table B-76. Bulk Density Thresholds
for Local Sensitivity By Soil Type^a*

Consequence of hazard	Assessed value	Threshold
Clayey Soil Texture		
Lowest	1	<1.10 g/cm ³
Moderate	3	1.10–1.47 g/cm ³
Highest	5	> 1.47 g/cm ³

^a USDA NRCS, *Soil Quality Indicators: Bulk Density*, June 2008, <http://soils.usda.gov/sqi/assessment/assessment.html>.

Metric 6: Soil Salinity

Metric 6 focuses on the salinity of the local soils. As discussed in Metric 3, soil salinization is a challenge as excess salts hinder the growth of crops by limiting their ability to take up water. Metric 3 estimates salinization based on the quantity of irrigation water applied per crop. However, some local soils are naturally saline or slightly saline and are prone to salinization, which is the focus of Metric 6.

Key measurements, databases, and tools for calculating Metric 6 include:

- ◆ USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>).

Table B-77 provides classifications of salt-affected soils. Saline soils are defined as having an electrical conductivity (EC) greater than 4 millimhos per centimeter (mmho/cm) at 25°C and SAR of less than 13 in their saturation extract. Although 4.0 mmho/cm is used as a general threshold EC to define saline soils, many sensitive crops such as some vegetables and ornamentals will show symptoms and reduced yields at ECs of 2–4 mmho/cm.¹¹¹ Saline soils can also be sodic (saline-sodic). Sodic soils have an abundance of sodium and saline-sodic soils generally have the same symptoms of saline soils.

Table B-77. Classification of Salt-affected Soils^a

Classification	Electrical conductivity (mmho/cm)	Soil pH	SAR
Slightly Saline	2-4	<8.5	<13
Saline	>4.0	<8.5	<13
Saline-Sodic	>4.0	<8.5	>13

^a Colorado State University Extension, *Diagnosing Saline and Sodic Soil Problems*, <http://www.ext.colostate.edu/pubs/crops/00521.html>.

¹¹¹ Colorado State University Extension, *Diagnosing Saline and Sodic Soil Problems*, <http://www.ext.colostate.edu/pubs/crops/00521.html>.

Once crop cultivation location is identified, NRCS's WSS should be used to identify the salinity of local soils. When accessing the WSS, the AOI is again defined and used to access the "Soil Data Explorer" tab. Access the "Soil Properties and Qualities" tab and select EC and SAR under the Soil Chemical Properties. If more than one soil is included in your AOI, use a weighted average based on all ECs/SARs in the AOI and the amount of land associated with each soil type.

Compare the EC/SAR levels of local soils to the levels presented in Table B-77 to determine their salinity. Apply these findings against the consequence thresholds presented in Table B-78 to determine the resultant impact rating.

Table B-78. Soil Salinity Thresholds for Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Lowest	1	Soils are neither saline nor sodic
Moderate	3	Soils are slightly saline
High	4	Soils are saline
Highest	5	Soils are saline-sodic

Metric 7: Irrigation Water Withdrawals (*State Level*)

Metric 7 focuses is on the salinity of the local soils, based on state irrigation water withdrawal content. As discussed in Metric 3, copious application of irrigation water can result in the addition of soluble salts, such as sodium, calcium, magnesium, potassium, sulfate, and chloride to local soils. Therefore, Metric 7 estimates a location's sensitivity to soil salinization burden as a function of the quantity of irrigation water applied at the state level. This metric is largely driven by the agricultural activities and local weather conditions present within a state.

Key measurements, databases, and tools for calculating Metric 7 include:

- ◆ USGS Irrigation Water Withdrawal Information (<http://ga.water.usgs.gov/edu/wuir.html>).

Once crop cultivation location(s) is identified, USGS's irrigation water withdrawal information should be used to identify the irrigation water withdrawals for the state being assessed. Apply these findings against the thresholds presented in Table B-79 to determine the resultant consequence rating.

Table B-79. Soil Salinity Thresholds for State Sensitivity

Consequence of hazard	Assessed value	Threshold
Lowest	1	0-200 million gal/day
Low	2	200–1,000 million gal/day
Moderate	3	1,000–5,000 million gal/day
High	4	5,000–15,000 million gal/day
Highest	5	15,000–25,000 million gal/day

Metric 8: BMPs Implemented

Metric 8 addresses the risk mitigation measures used to reduce soil quality raw risk scores. In this case, BMPs to mitigate soil quality hazards include, but are not limited to:

- ◆ avoiding performing field operations on wet soils,
- ◆ limiting vehicle load and ensuring proper weighting in tillage operations,
- ◆ managing vehicle traffic within fields,
- ◆ addressing drainage problems,
- ◆ adding organic materials to help build soil structure and increase soil strength,
- ◆ rotating to tap-rooted forages to create channels in the soil that subsequent crops can use, and
- ◆ modifying soil tillage practices.

If feedstock producers have BMPs implemented, this mitigation metric should necessitate a reassessment of Metrics 1–3 hazard likelihood ratings. These adjustments will generate an adjustment of the indicator’s raw risk numbers.

General Considerations, Assumptions, and Uncertainties

The proposed metrics were developed as a representative but simple means to estimate soil quality risks, particularly focused on biomass cultivation. As such, the listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and gaps associated with data availability and reporting will arise, particularly for emerging energy crops where little data is available.

RESOURCES AND CAPABILITIES

Keystone Resources

USDA, Census of Agriculture, *Farm and Ranch Irrigation Survey*, 2008, Table 28, (http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.php)

USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>)

Supplementary Supporting Capabilities

For deeper analysis, a Soil Condition Index (SCI) tool is available in the Revised Universal Soil Loss Equation, Version 2 (RUSLE2).¹¹² The SCI tool predicts the effects of management systems on SOM and may be useful for assessing the mitigation effectiveness of BMPs.

REFERENCES

Anderson-Teixeira KJ, Davis SC, Masters MD, DeLucia EH, “Changes in soil organic carbon under biofuel crops,” 2009, *GCB Bioenergy*, Volume 1:75–96 <http://www.life.illinois.edu/delucia/publications.htm>.

Colorado State University Extension, *Diagnosing Saline and Sodic Soil Problems*, <http://www.ext.colostate.edu/pubs/crops/00521.html>.

FAO, *The importance of soil organic matter*, <ftp://ftp.fao.org/agl/agll/docs/sb80e.pdf>.

GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

McBride, Allen C., Virginia H. Dalea, Latha M. Baskarana, Mark E. Downing, Laurence M. Eaton, Rebecca A. Efroymson, Charles T. Garten Jr., Keith L. Kline, Henriette I. Jager, Patrick J. Mulholland, Esther S. Parisa, Peter E. Schweizer, John M. Storey, “Indicators to support environmental sustainability of bioenergy systems,” *Ecological Indicators* 11 (2011), p. 1277–1289.

Soil Quality for Environmental Health, *Soil Quality Indicators: Measures of Soil Functional State*, <http://soilquality.org/indicators.html>.

¹¹² USDA ARS, *Revised Universal Soil Loss Equation 2—Overview of RUSLE 2*, April 2010, http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

Soil Quality for Environmental Health, *Total Organic Carbon*,
http://soilquality.org/indicators/total_organic_carbon.html.

Soil Quality for Environmental Health, *Value of Soil*, <http://soilquality.org/basics/value.html>.

University of Minnesota Extension, *Soil Compaction: Causes, Effects and Control*, <http://www.extension.umn.edu/distribution/cropsystems/components/3115s01.html>

University of Wisconsin Extension, *Soil Compaction: Causes, Concerns, and Cures*, A3367, Richard Wolkowski & Birl Lowery, 2008,
<http://www.soils.wisc.edu/extension/pubs/A3367.pdf>.

USDA ARS, *Frequently Asked Questions About Salinity*,
<http://www.ars.usda.gov/Aboutus/docs.htm?docid=10201>.

USDA ARS, *Revised Universal Soil Loss Equation 2—Overview of RUSLE 2*, April 2010, http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

USDA NRCS, *Soil Quality Indicators: Bulk Density*, June 2008,
<http://soils.usda.gov/sqi/assessment/assessment.html>.

USDA NRCS, *Soil Quality Indicator Guide Sheet*, September 2009,
<http://soils.usda.gov/sqi/assessment/assessment.html>.

USDA NRCS, *Soil Quality Resource Concerns: Salinization*, January 1998,
www.urbanext.illinois.edu/soil/sq_info/saline.pdf.

USDA, NRCS, *Soil Quality/Soil Health Concepts*, <http://soils.usda.gov/sqi/concepts/concepts.html>.

USDA NRCS, *Soil Quality/Soil Health*, <http://soils.usda.gov/sqi/>.

Nutrient Requirements and Fertilizer Use

Pillar	Environmental
Criteria	Productivity
Indicator	Nutrient Requirements and Fertilizer Use

Nutrients are considered any element or biologically accessible compounds essential for feedstock growth, particularly for nitrogen, phosphorus, and potassium.¹¹³ When the soil or other growth media cannot supply the level of building block nutrients required for adequate growth, supplemental fertilizer applications become necessary to maintain agricultural productivity.¹¹⁴ Soil fertility depends on the combination and proportions of nutrients added, proper timing in the growth cycle, cultivation method use, and soil temperature.¹¹⁵ According to Penn State University's Agronomy Guide, "low to medium application rates provide the greater plant response and often the greatest economic return per dollar invested."¹¹⁶

Nutrient management requires an understanding of the rate, timing, form, and method of nutrient delivery to support soil fertility for optimal plant production and to minimize the potential for environmental degradation, particularly air, soil, and water quality impacts. Managing nutrient requirements and fertilizer use for biofuels can vary greatly depending on the feedstock type, cropping system, and local soil conditions. Therefore, considering the nutrient management requirements of each biofuel is key to components for understanding and mitigating the sustainability supply chain risk associated with fertilizer inputs.

The application of fertilizers is often needed for profitable agricultural crop production, but it is a major input cost and can easily contribute to environmental degradation, particularly downstream soil and water quality. According to the NASS, approximately \$25 billion dollars were spent in the United States on fertilizers in 2011.¹¹⁷ A significant portion of these were applied to agricultural fields but are later carried by water run-off into lakes, rivers, and, ultimately, drinking water. Therefore, effective understanding of nutrients requirements and appropri-

¹¹³ USDA, NRCS, National Agronomy Manual, February 2011, <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/agronomy>.

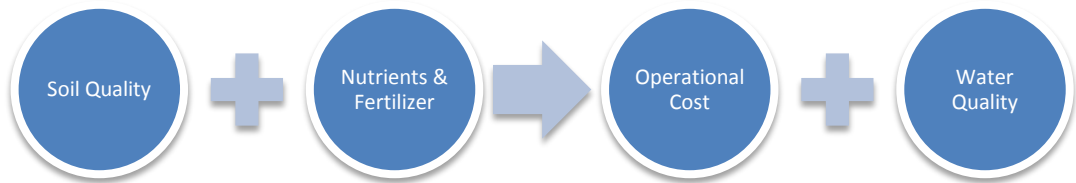
¹¹⁴ University of Minnesota Extension, Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota, 2012, Carl J. Rosen and Roger Eliason, <http://www.extension.umn.edu/distribution/cropsystems/DC5886.html>.

¹¹⁵ EPA, *Nutrient Management*, <http://www.epa.gov/oecaagct/ag101/croplandnutrientmgt.html>.

¹¹⁶ Penn State Extension, The Agronomy Guide 2011–12, <http://extension.psu.edu/agronomy-guide/cm/sec2>.

¹¹⁷ USDA NASS Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

ate fertilizer use is essential to the economic viability of biofuel supply chains but also in managing their environmental impacts on water quality.



RELEVANCE AND RATIONALE

Effective nutrient management leads to more sustainable and economical cultivation of bioenergy feedstocks. Despite its importance, Table B-80 highlights the limited number of instances where nutrient management appears in biofuel sustainability-related statutes. However, there are several biofuel sustainability frameworks and standards that incorporate nutrients management considerations as aspects of soil and water quality due to their associated environmental impacts.

Table B-80. Nutrient and Fertilizer Statutory, USG Policy, and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
Biomass Research and Development Act of 2000		Yes	
EISA of 2007		Yes	
National Environmental Protection Act of 1970	Yes		

METRICS SELECTED

Nutrient metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics amiable for quantitative comparisons among drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the nutrients hazard posed by a particular feedstock crop and cultivation system; and, second, quantification of the location specific sensitivity for the related nutrient requirements.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Average nitrogen fertilizer application rates for feedstocks, pounds (lbs)/acre/year
- ◆ Metric 2: Average phosphorus fertilizer application rates for feedstocks, lbs/acre/year

- ◆ Metric 3: Average potassium fertilizer application rates for feedstocks, lbs/acre/year

Regional or Site Assessment Sensitivity (Consequence Metrics)¹¹⁸

- ◆ Metric 4: Available phosphorus in local soils, parts per million (ppm)
- ◆ Metric 5: Available potassium in local soils, ppm

Risk Reduction (Mitigation Metrics)

- ◆ Metric 6: Nutrient management plan in place and implemented

The applicability of nutrients has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-81 summarizes these applicability findings.

Table B-81. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Average nitrogen fertilizer application rates	Yes	No	Minimal	No	No
Metric 2: Average phosphorus fertilizer application rates	Yes	No	Minimal	No	No
Metric 3: Average potassium fertilizer application rates	Yes	No	Minimal	No	No
Metric 4: Available phosphorus in local soils	Yes	No	No	No	No
Metric 5: Available potassium in local soils	Yes	No	No	No	No
Metric 6: Nutrient management plan in place and implemented	Yes	No	No	No	No

¹¹⁸ Available nitrogen in local soils is not listed as a consequence metric because the majority of the routine suite of soil tests does not estimate soil nitrogen availability. This is because soil nitrogen exists in several forms and changes over time. Instead, recommended nitrogen application rates are tailored based on crop nitrogen needs and local soil conditions. Recommended nitrogen fertilizer application rates are solely captured by Metric 1.

MEASUREMENT AND ANALYSIS APPROACH

Nutrient requirement and fertilizer use metrics are largely oriented on the feedstock cultivation stage of a given biofuel pathway. At a minimum, the following metrics are required to first determine crop's nutrient and fertilizer demand under optimal circumstances; and, second, the local sensitivity to this demand based upon local soil nutrient richness. With these two metrics in place, the raw fertilizer demand risk can be estimated and later mitigated through purposeful nutrient management planning.

Metric 1: Average Nitrogen Fertilizer Application Rates

Metric 1 focuses on average nitrogen fertilizer application rates for various crops. This metric is greatly impacted by the crop type, local soil conditions, and management practices used.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ USDA, NASS, Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).
- ◆ State land-grant universities local nitrogen fertilizer application recommendations. A list of state land-grant universities can be found at: http://www.higher-ed.org/resources/land_grant_colleges.htm.
- ◆ Soil tests provided by feedstock producers.

Table B-82 provides average national nitrogen fertilizer application rates for various crops.

Table B-82. Average Nitrogen Fertilizer Application Rates^a

Crop	Average nitrogen fertilizer application (lbs/acre/year)	Year ^b
Rice	183	2006
Corn	140	2010
Sugarbeets	109	2000
Cotton	91	2007
Tobacco, Flue-cured (Class 1)	88	1996
Corn, Organic	78	2010
Wheat, Spring, (Excl Durum)	78	2009
Cotton, Upland	77	2010
Barley	72	2011
Sorghum	67	2011

Table B-82. Average Nitrogen Fertilizer Application Rates^a

Crop	Average nitrogen fertilizer application (lbs/acre/year)	Year ^b
Sunflower	67	1999
Wheat, Spring, Durum	61	2009
Wheat, Winter	61	2009
Oats	54	2005
Peanuts	36	2004
Wheat, Winter, Organic	31	2009
Soybeans	16	2006
Wheat, Spring, (Excl Durum), Organic	4	2009

^a Average nitrogen fertilizer application rates are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the NASS Quick Stats 2.0 database.

The average nitrogen fertilizer application rates provided in Table B-82 are representative of national averages. However, fertilizer application rates depend on local conditions and, therefore, can vary greatly among states, regions, and localities. As such, state, regional or local averages should be used to the full extent possible. Soil tests of individual agricultural fields will often include nitrogen fertilizer recommendations that are based on the crop grown and type of local soil. If soil assessments from feedstock producers are not available, state land-grant universities often recommend nitrogen fertilizer application rates for the various crops and soil type combinations. Nitrogen fertilizer application rates are also available at the state level for some states on USDA NASS Quick Stats 2.0 database (see above). If local and state rates are not available, the national levels provided in Table B-82 can be used with the recognition that these rates may not be an accurate reflection of state, region, or locality specific application rates.

Once appropriate nitrogen fertilizer application rates are identified, this metric is used for evaluating a nutrient requirements hazard of a particular feedstock. Table B-83 shows hazard thresholds based on the nitrogen fertilizer application rates, provided in Table B-82. However, these threshold levels should be revised considering state nitrogen fertilizer application rates, as available.

Table B-83. Average Nitrogen Fertilizer Application Rates Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<37 lbs/acre/year
Low	2	37–75 lbs/acre/year
Moderate	3	76–114 lbs/acre/year
High	4	115–151 lbs/acre/year
Highest	5	>151

Metric 2: Average Phosphorus Fertilizer Application Rates

Metric 2 focuses on average phosphorus fertilizer application rates for various crops. This metric is greatly impacted by the crop type, local soil conditions, and management practices used.

Key measurements, databases, and tools for calculating Metric 2 include:

- ◆ USDA, NASS, Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

Table B-84 provides average national phosphorus fertilizer application rates for existing commodity crops.

Table B-84. Average Phosphorus Fertilizer Application Rates^a

Crop	Average phosphorus fertilizer application (lbs/acre/year)	Year ^b
Tobacco, Flue-Cured (Class 1)	93	1996
Sugarbeets	70	2000
Corn	60	2010
Rice	53	2006
Wheat, Winter, Organic	53	2009
Peanuts	50	2004
Soybeans	46	2006
Cotton	43	2007
Cotton, Upland	37	2010
Oats	35	2005
Wheat, Spring, (Excl Durum)	31	2009
Wheat, Winter	31	2009

Table B-84. Average Phosphorus Fertilizer Application Rates^a

Crop	Average phosphorus fertilizer application (lbs/acre/year)	Year ^b
Barley	30	2011
Corn, Organic	30	2010
Sunflower	27	1999
Sorghum	26	2011
Wheat, Spring, Durum	25	2009
Wheat, Spring, (Excl Durum), Organic	2	2009

^a Average phosphorus fertilizer application rates are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the NASS Quick Stats 2.0 database.

The average phosphorus fertilizer application rates provided in Table B-84 are representative of national averages. However, as with Metric 1, fertilizer application rates depend on local conditions and can vary greatly among states and regions. As such, state averages application rates should be used to the extent possible. Phosphorus fertilizer application rates are available at the state level for some states on USDA NASS Quick Stats 2.0 database. If state rates are not available, the national levels provided in Table B-84 can be used, recognizing that the rates may not be an accurate reflection of state application rates.

Once appropriate phosphorus fertilizer application rates are identified, this metric is used for evaluating the nutrient requirements hazard. Table B-85 shows hazard thresholds based on the phosphorus fertilizer application rates provided in Table B-84. However, these threshold levels should be revised with state specific phosphorus fertilizer application rates as they are available.

Table B-85. Average Phosphorus Fertilizer Application Rates Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<19 lbs/acre/year
Low	2	20–39 lbs/acre/year
Moderate	3	40–59 lbs/acre/year
High	4	60–79 lbs/acre/year
Highest	5	>80

Metric 3: Average Potassium Fertilizer Application Rates

Similar to Metric 2, Metric 3 is oriented on average potassium fertilizer application rates for various crops. This metric can likewise be greatly influenced by the crop type, local soil conditions, and management practices.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA, NASS, Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

Table B-86 provides average national potassium fertilizer application rates for various crops.

Table B-86. Average Potassium Fertilizer Application Rates^a

Crop	Average potassium fertilizer application (lbs/acre/year)	Year ^b
Tobacco, Flue-Cured (Class 1)	203	1996
Soybeans	80	2006
Corn	79	2010
Peanuts	79	2004
Sugarbeets	75	2000
Cotton	70	2007
Cotton, Upland	66	2010
Rice	65	2006
Oats	50	2005
Wheat, Winter	39	2009
Wheat, Winter, Organic	33	2009
Corn, Organic	29	2010
Barley	24	2011
Wheat, Spring, (Excl Durum)	23	2009
Sorghum	16	2011
Wheat, Spring, Durum	11	2009
Sunflower	7	1999
Wheat, Spring, (Excl Durum), Organic	2	2009

^a Average potassium fertilizer application rates are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the NASS Quick Stats 2.0 database.

As with Metrics 1 and 2, the US average potassium fertilizer application rates are provided in Table 7. State averages from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp) should be used to the full extent possible. If state rates are not available, the national levels provided in Table B-61 can be used, recognizing that these may not accurately reflect state, region, or locality specific application rates.

Once the applicable potassium fertilizer application rates are identified, this metric is used for evaluating the nutrient requirements hazard. Table B-87 shows hazard thresholds based on the potassium fertilizer application rates provided in Table B-86. However, these threshold levels should be reviewed and, if necessary revised, with state potassium fertilizer application rates should they be available.

Table B-87. Average Potassium Fertilizer Application Rates Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<41 lbs/acre/year
Low	2	42–83 lbs/acre/year
Moderate	3	84–125 lbs/acre/year
High	4	126–167 lbs/acre/year
Highest	5	>167

Metric 4: Available Phosphorus in Local Soils

Metric 4 reflects the fertility of local soils based on available phosphorus in soils.

Key measurements, databases, and tools for calculating Metric 4 include:

- ◆ Soil tests for phosphorous provided by feedstock producers.
- ◆ State land-grant university state soil health resources that can be found at: http://www.higher-ed.org/resources/land_grant_colleges.htm.

State land-grant universities study and generate phosphorus application rate recommendations for individual fields based upon local soil test results. Therefore, the concentration of available phosphorus in local soils informs the producers on the needed quantity of phosphorus fertilizer so as to ensure optimal productivity. If soil tests are not available from feedstock producers, state land-grant universities may be able to provide general information on soil fertility. For example, the University of Wisconsin Extension provides a state map that shows general sub-soil fertility groups based on available phosphorus and potassium in subsoils.¹¹⁹

¹¹⁹ University of Wisconsin Extension, Optimal Soil Test Levels for Wisconsin, 1999, UWEX A3030, Kelling et al, <http://www.soils.wisc.edu/extension/soilsampling.php>.

Once the available phosphorus is determined, this metric helps evaluate the local sensitivity to nutrient depletion. Table B-88 shows consequence thresholds based on optimal soil-phosphorus ranges, as provided by the University of Arkansas and Penn State University.^{120,121} However, these threshold levels should be revised with state or regional specific optimal phosphorus ranges as developed and provided by the state land-grant university, where available.

Table B-88. Available Phosphorus in Local Soils Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	>50 ppm
Low	2	31–50 ppm
Moderate	3	26–30 ppm
High	4	16–29 ppm
Highest	5	<16 ppm

Metric 5: Available Potassium in Local Soils

Metric 5 reflects the fertility of local soils, based on available potassium in soils.

Key measurements, databases, and tools for calculating Metric 5 include:

- ◆ Soil tests for phosphorous provided by feedstock producers.
- ◆ State land-grant university state soil health resources that can be found at: http://www.higher-ed.org/resources/land_grant_colleges.htm.

Parallel to Metric 4, the quantity of available potassium in local soils dictates the quantity of potassium fertilizer required to maintain optimal productivity. If soil tests from feedstock producers are not available, state land-grant universities may be able to provide general information on soil fertility.

Once the available potassium in local soils is determined, this metric should be used to evaluate local sensitivity. Table B-89 shows consequence thresholds based on optimal soil-potassium ranges provided by the University of Arkansas and Penn State University.^{122,123} However, these threshold levels should be re-

¹²⁰ University of Arkansas Division of Agriculture Research & Extension, Understanding the Numbers on Your Soil Test Report, FSA2118, Leo Espinoza et al., http://www.uaex.edu/Other_Areas/publications/PDF/FSA-2118.pdf.

¹²¹ Penn State Extension, The Agronomy Guide 2011-12, Table 1.2-5, <http://extension.psu.edu/agronomy-guide/cm/sec2>.

¹²² University of Arkansas Division of Agriculture Research & Extension, Understanding the Numbers on Your Soil Test Report, FSA2118, Leo Espinoza et al., http://www.uaex.edu/Other_Areas/publications/PDF/FSA-2118.pdf.

vised with optimal potassium ranges provided by the state land-grant university, where available.

Table B-89. Available Potassium in Local Soils Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	>175 ppm
Low	2	131–175 ppm
Moderate	3	91–130 ppm
High	4	61–90 ppm
Highest	5	<61 ppm

Metric 6: Nutrient Management Plan

Metric 6's purpose is to assess whether a nutrient management plan is available and being used to mitigate nutrient management risks associated with biofuel feedstock production. The key qualitative question is:

- ◆ A nutrient management plan in place and implemented?

If feedstock producers have developed a nutrient management plan, then reassessment of Metrics 1, 2, and/or 3 hazard ratings is needed. The reassessment may justify a reduction of the raw risk number due to a reduced likelihood hazard and lower upstream vulnerabilities and downstream impact risks.

General Considerations, Assumptions, and Uncertainties

The proposed metrics were developed as a representative but simple means to estimate nutrient and fertilizer use requirements, consequences, and mitigations, particularly relevant to biomass cultivation. As such, the listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and gaps associated with data availability and reporting will likely arise, particularly for emerging energy crops where little data is available.

¹²³ Penn State Extension, The Agronomy Guide 2011-12, Table 1.2-5, <http://extension.psu.edu/agronomy-guide/cm/sec2>.

RESOURCES AND CAPABILITIES

Keystone Resources

USDA NASS Chemical Use Data in Quick Stats 2.0 database
http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp

State land-grant universities (http://www.higher-ed.org/resources/land_grant_colleges.htm)

Supplementary Supporting Capabilities

For deeper analysis at the regional and local levels, a fertilizer calculator is available for select states from Purdue University
(<http://www.agry.purdue.edu/mmp/webcalc/fertRec.asp>).

REFERENCES

EPA, *Nutrient Management*, <http://www.epa.gov/oecaagct/ag101/croplandnutrientmgt.html>.

Iowa State University Extension, *Nitrogen Fertilizer Recommendations for Corn in Iowa*, PM-1714, May 1997, <https://store.extension.iastate.edu/ItemDetail.aspx?ProductID=5259>.

Penn State Extension, *The Agronomy Guide 2011-12*,
<http://extension.psu.edu/agronomy-guide/cm/sec2>.

University of Arkansas Division of Agriculture Research & Extension, *Nitrogen Recommendations for Corn*, April 11, 2012, Leo Espinoza,
<http://www.arkansas-crops.com/2012/04/11/nitrogen-recommendations-for-corn/>.

University of Arkansas Division of Agriculture Research & Extension, *Understanding the Numbers on Your Soil Test Report*, FSA2118, Leo Espinoza, Nathan Slaton, Morteza Mozaffari, http://www.uaex.edu/Other_Areas/publications/PDF/FSA-2118.pdf.

University of Minnesota Extension, *Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota*, 2012, Carl J. Rosen and Roger Eliason,
<http://www.extension.umn.edu/distribution/cropsystems/DC5886.html>.

University of Wisconsin Extension, *Optimal Soil Test Levels for Wisconsin*, 1999, UWEX A3030, K.A. Kelling, L.G. Bundy, S.M. Combs, J.B. Peters,
<http://www.soils.wisc.edu/extension/soilsampling.php>.

USDA, NASS Chemical Use Data in Quick Stats 2.0 database,
http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp.

USDA, NRCS, *National Agronomy Manual*, February 2011,
<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/agronomy>.

Pesticide Use

Pillar	Environmental
Criteria	Productivity
Indicator	Pesticide Use

The US EPA defines pesticides as “any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest.”¹²⁴ Pesticides are used to control a range of agricultural pests including fungicides, herbicides, and insecticides. The FIFRA provides EPA with the statutory authority to regulate pesticides, in conjunction with other relevant agencies, such as the US Food and Drug Administration, USDA, and USFWS. In addition to national regulations, states have additional authority to regulate pesticides.¹²⁵

As with fertilizer application, the pesticide application is often needed for profitable agricultural crop production but is a major input cost, can easily impact human health, and contribute to environmental degradation. According to the NASS, approximately \$10 billion dollars were spent in the United States on agricultural chemicals in 2007.¹²⁶ Pesticides, when used incorrectly, can harm workers, and pollute soil, surface water, and even drinking water aquifers. In addition, pesticides can have detrimental effects on wildlife and their habitats. Therefore, understanding of pesticide requirements, their safety handling, and their effective application is essential to the economic viability of biofuel supply chains and in managing their environmental impacts.



RELEVANCE AND RATIONALE

Effective pesticide management can contribute to more sustainable and economical cultivation of bioenergy feedstocks. Despite its importance, Table B-90 highlights the limited number of instances where pesticide management appears in biofuel- and sustainability-related statutes.

¹²⁴ EPA, *About Pesticides*, <http://www.epa.gov/pesticides/about/index.htm>.

¹²⁵ National Pesticide Information Center, *Federal Pesticide Regulation*, <http://npic.orst.edu/reg/regfed.html>.

¹²⁶ USDA NASS Chemical Use Data in Quick Stats 2.0 database, http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp.

Table B-90. Pesticide Use Statutory and DoD Policy Relevance

	General relevance	Direct relevance	Proposes metric
Statutory and Regulatory Relevance			
EISA of 2007		Yes	
National Environmental Protection Act of 1970	Yes		
FIFRA		Yes	
DoD and Service Policy Relevance			
DoD SSPP FY 10	Yes		
DoD SSPP FY 11	Yes		

Pesticide use indicators are only addressed by a limited number of bioenergy frameworks and standards (Table B-91).

Table B-91. Pesticide Use in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Pesticide use metrics were identified and selected to reflect feedstock and conversion pathway characteristics applicable for meaningful comparisons across drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the pesticide use hazard posed by a particular feedstock crop and cultivation system; and, second, the local or regional sensitivities assessment for pesticide use.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Average annual fungicide treatments, % of area planted
- ◆ Metric 2: Average annual herbicide treatments, % of area planted
- ◆ Metric 3: Average annual insecticide treatments, % of area planted¹²⁷

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 4: Water body impairment for pesticides

¹²⁷ USDA NASS includes data on agricultural chemical use for several categories including fungicides, herbicides, insecticides, and “other.” Note that the “other” category was not included as a metric because the exact use of these chemicals is not always clear.

- Local receiving water body or watershed listed as “impaired” for pesticides, Yes/No
- MDL established for pesticides, Yes/No

Risk Reduction (Mitigation Metrics)

- ◆ Metric 5: Integrated Pest Management (IPM) plan in place or USDA-certified organic

Pesticide use has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-92 summarizes these applicability findings.

Table B-92. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Average annual fungicide treatments	Yes	No	No	No	No
Metric 2: Average annual herbicide treatments	Yes	No	No	No	No
Metric 3: Average annual insecticide treatments	Yes	No	No	No	No
Metric 4: Water body impairment for pesticides	Yes	No	No	No	No
Metric 5: IPM plan in place or USDA-certified organic	Yes	No	No	No	No

MEASUREMENT AND ANALYSIS APPROACH

Pesticide use metrics are largely oriented on the feedstock cultivation stage of a given biofuel pathway. At a minimum, the following metrics are required to first determine a crop’s pesticide use under normal circumstances; and, second, the local sensitivity to this level of application rate based upon existing pesticide pollution. With these two metrics in place, the raw pesticide use risk can be estimated and later mitigated through the use of IPM or organic farming practices.

Metric 1: Average Annual Fungicide Treatments

Metric 1 reflects the average annual fungicide treatments for various crops. This metric is greatly influenced by the crop type, local environmental conditions, pest burden, and management practices.

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ USDA NASS Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

Table B-93 provides average annual fungicide treatments applied for various crops for the most recent year available on the USDA NASS Quick Stats 2.0 database.

Table B-93. Average Annual Fungicide Treatments^a

Crop	Average annual fungicide treatments (% of area planted)	Year ^b
Peanuts	93	2004
Sugarbeets	72	2000
Tobacco, Flue-cured (Class1)	49	1996
Rice	41	2006
Wheat, Spring, (Excl Durum)	36	2009
Barley	24	2011
Wheat, Spring, Durum	23	2009
Corn	8	2010
Wheat, Winter	7	2009
Soybeans	4	2006
Cotton	1	2007
Cotton, Upland	1	2010
Wheat, Post Harvest	0.1	2009

^a Average annual fungicide treatments are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the USDA NASS Quick Stats 2.0 database.

The average annual fungicide treatments provided in Table B-93 represent national averages. However, fungicide treatments vary greatly under local conditions and therefore, among states. As such, state averages or local values should be used if at all possible. At the state level, fungicide treatment data are available in USDA NASS Quick Stats 2.0 database. If state rates are not available, the national levels provided in Table B-93 can be used, recognizing that the rates may not accurately reflect state or local application rates.

Once appropriate fungicide treatment rates are identified, this metric is used to evaluate the fungicide requirements hazard. Table B-94 shows hazard thresholds based on the fungicide treatment rates. However, these threshold levels should be revised with state fungicide treatment rates should the location be known and application rates available.

Table B-94. Average Annual Fungicide Treatments Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<20% of area planted
Low	2	20–40% of area planted
Moderate	3	41–60% of area planted
High	4	61–80% of area planted
Highest	5	>80% of area planted

Metric 2: Average Annual Herbicide Treatments

Metric 2 reflects the average annual herbicide treatments applied to various crops. This metric is greatly influenced by the crop type, local conditions, and management practices.

Key measurements, databases, and tools for calculating Metric 2 include:

- ◆ USDA NASS Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

Table B-95 provides average annual herbicide treatments applied for various crops for the most recent year available on the USDA NASS Quick Stats 2.0 database.

Table B-95. Average Annual Herbicide Treatments^a

Crop	Average annual herbicide treatments (% of area planted)	Year ^b
Wheat, Spring, Durum	100	2009
Cotton, Upland	99	2010
Corn	98	2010
Peanuts	98	2004
Soybeans	98	2006
Sugarbeets	98	2000
Cotton	97	2007
Wheat, Spring, (Excl Durum)	97	2009
Rice	95	2006
Sunflowers	95	1999
Sorghum	86	2011
Barley	83	2011
Tobacco, Flue-cured (Class1)	75	1996

Table B-95. Average Annual Herbicide Treatments^a

Crop	Average annual herbicide treatments (% of area planted)	Year ^b
Wheat, Winter	60	2009
Oats	31	2005

^a Average annual herbicide treatments are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the USDA NASS Quick Stats 2.0 database.

The average annual herbicide treatments provided in Table B-95 represent national averages. However, herbicide treatments vary greatly under local conditions and therefore, among states. As such, state averages or local values should be used if at all possible. At the state level, herbicide treatment data are available in USDA NASS Quick Stats 2.0 database. If state rates are not available, the national levels provided in Table B-95 can be used, recognizing that the rates may not accurately reflect state or local application rates.

Once appropriate herbicide treatment rates are identified, this metric is used to evaluate the herbicide requirements hazard. Table B-96 shows hazard thresholds based on the herbicide treatment rates. However, these threshold levels should be revised with state herbicide treatment rates should the location be known and application rates available.

Table B-96. Average Annual Herbicide Treatments Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<20% of area planted
Low	2	20–40% of area planted
Moderate	3	41–60% of area planted
High	4	61–80% of area planted
Highest	5	>80% of area planted

Metric 3: Average Annual Insecticide Treatments

Metric 3 reflects the average annual insecticide treatments applied for various crops. This metric is greatly influenced by the crop type, local conditions, and management practices.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA NASS Chemical Use Data in Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

Table B-97 provides average annual insecticide treatments applied for various crops for the most recent year available in the USDA NASS Quick Stats 2.0 database.

Table B-97. Average Annual Insecticide Treatments^a

Crop	Average annual insecticide treatments (% of area planted)	Year ^b
Tobacco, Flue-cured (Class1)	96	1996
Cotton	66	2007
Peanuts	66	2004
Sugarbeets	63	2000
Cotton, Upland	55	2010
Sunflower	33	1999
Rice	21	2006
Wheat, Post Harvest	18.1	2009
Soybeans	16	2006
Corn	12	2010
Barley	6	2011
Sorghum	6	2011
Wheat	6	2009
Wheat, Spring, (Excl Durum)	5	2009
Oats	4	2005
Wheat, Spring, Durum	4	2009

^a Average annual insecticide treatments are from USDA NASS Quick Stats 2.0 database (http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp).

^b Rates provided are the most recent year available in the USDA NASS Quick Stats 2.0 database.

The average annual insecticide treatments provided in Table B-97 represent national averages. However, insecticide treatments vary greatly under local conditions and therefore, among states. As such, state averages or local values should be used if at all possible. At the state level, insecticide treatment data are available in USDA NASS Quick Stats 2.0 database. If state rates are not available, the national levels provided in Table B-97 can be used, recognizing that the rates may not accurately reflect state or local application rates.

Once appropriate insecticide treatment rates are identified, this metric is used to evaluate the insecticide requirements hazard. Table B-98 shows hazard thresholds based on the insecticide treatment rates. However, these threshold levels should be revised with state insecticide treatment rates should the location be known and application rates available.

Table B-98. Average Annual Insecticide Treatments Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<20% of area planted
Low	2	20–40% of area planted
Moderate	3	41–60% of area planted
High	4	61–80% of area planted
Highest	5	>80% of area planted

Metrics 4: Water Body Impairment for Pesticides

As a consequence component, Metric 4 focuses on whether the local water body or watershed is listed as impaired because of pesticide pollution. Section 303(d) of the CWA requires states, territories, and authorized tribes to develop lists of impaired waters. This designation indicates that these waters are too polluted or otherwise degraded to meet their respective water quality standards. If a receiving water body is listed as impaired for a particular pollutant, this is indicative of a high regional or local sensitivity for the identified pollutant, such as pesticides. Section 303(d) likewise requires that these jurisdictions establish priority lists for these water bodies and develop TMDLs for the specific pollutants of concern. In short, a TMDL is a calculation of the maximum amount of a particular pollutant that a waterbody can receive and still safely meet established water quality standards.¹²⁸

Key measurements, databases, and tools for calculating Metric 4 include:

- ◆ EPA’s Water Quality Assessment and TMDLs (<http://www.epa.gov/waters/ir/>)
- ◆ State regulatory authorities (e.g., Illinois TMDL program is managed by the Illinois Environmental Protection Agency)

Once a pathway’s location(s) is identified, EPA’s Water Quality Assessment and TMDL Information Portal should be used to identify whether the local receiving waters or watersheds are listed as impaired for pesticides. Note that waterbodies can be listed as impaired for pesticides in general or for specific pesticides (e.g.,

¹²⁸ EPA, “*Impaired Waters and Total Maximum Daily Loads*,” September 2012, <http://water.epa.gov/lawsregs/lawguidance/cwa/tmdl/index.cfm>.

atrazine, etc.). Further, determine if a TMDL for these pollutants has been established or is under development for these water bodies or watersheds.

Apply these findings against the thresholds presented in Table B-99 to determine the resultant consequence of this pollutant hazard.

Table B-99. Pesticide Thresholds for Watershed or Local Sensitivity

Consequence of hazard	Assessed value	Threshold
Low	2	Local receiving water bodies and watershed(s) are not on impaired list due to general or specific pesticides.
Moderate	3	Local receiving water bodies and watershed(s) are listed on the impaired list due to general or specific pesticides, but TMDLs for these pollutants have not been established.
Highest	5	General or specific pesticides TMDL(s) is under development or already established for the local water bodies and watershed(s).

Metric 5: IPM Plan in Place or USDA-Certified Organic

Metric 5's purpose is to assess whether an IPM plan is available and being used to mitigate pesticide use risks associated with biofuel feedstock production. Metric 5 assesses whether a farm has been certified organic by a USDA accredited certifying agent.¹²⁹ If feedstock producers have developed and implemented an IPM plan or if the feedstock is being produced on a certified organic farm, then Metrics 1, 2, and/or 3 hazard ratings should be reassessed. This may result in a reduction of the original raw risk number due to a reduced likelihood of hazard.

General Considerations, Assumptions, and Uncertainties

The proposed metrics have been developed as a representative but simple means to estimate pesticide use hazards, consequences, and mitigations, particularly relevant to biomass cultivation. As such, the listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and gaps associated with data availability and reporting will arise, particularly for emerging energy crops where little pesticide use data is collected or available.

¹²⁹ USDA, *National Organic Program*, "USDA Accredited Certifying Agents," <http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?template=TemplateJ&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPACAs&description=USDA%20Accredited%20Certifying%20Agents&acct=nopgeninfo>.

RESOURCES AND CAPABILITIES

Keystone Resources

USDA NASS Chemical Use Data in Quick Stats 2.0 database
(http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp)

EPA's Water Quality Assessment and TMDLs (<http://www.epa.gov/waters/ir/>)

REFERENCES

EPA, *About Pesticides*, <http://www.epa.gov/pesticides/about/index.htm>.

EPA, *Impaired Waters and Total Maximum Daily Loads*, September 2012,
<http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm>.

National Pesticide Information Center, *Federal Pesticide Regulation*,
<http://npic.orst.edu/reg/regfed.html>.

USDA NASS Chemical Use Data in Quick Stats 2.0 database,
http://www.nass.usda.gov/Statistics_by_Subject/Environmental/index.asp

USDA, *National Organic Program*, "USDA Accredited Certifying Agents,"
<http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateJ&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPACAs&description=USDA%20Accredited%20Certifying%20Agents&acct=nopgeninfo>.

Invasive Species

Pillar	Environmental
Criteria	Biological Resources
Indicator	Invasive Species

EO 13112 defines an “invasive species” as:

- 1) Non-native (or alien) to the ecosystem under consideration, and
- 2) Whose introduction causes or is likely to cause economic or environmental harm or harm to human health.¹³⁰

It is estimated that 50,000 non-native species have been introduced to the United States, including livestock, crops, pets, and other non-invasive species. Economic damages associated with invasive species’ effects and control costs are estimated at \$120 billion per year.¹³¹ After an invasive species is introduced, it is, by definition, often extremely successfully competing in a new ecosystem, displaces native species, and disrupts important ecosystem processes.¹³² Bioenergy crops, while having an economic benefit, could have the potential to escape cultivation and become invasive in natural and even managed ecosystems. Several of the candidate biofuel feedstock species being considered for commercial production in the US are considered invasive species in certain parts of the country.¹³³ For example, of the many grasses being considered and evaluated as bioenergy crops, a few have already been shown to be extremely invasive in many communities (e.g., giant reed [*Arundo donax*] and reed canarygrass [*Phalaris arundinacea*]).¹³⁴ From an ecological perspective, invasive plants can cause dramatic ecosystem changes that impact both plant and animal communities, including a loss of biodiversity and habitat destruction.

Invasive species can not only threaten the environmental resources but can also result in severe economic consequences. From an economic standpoint, invasive

¹³⁰ USDA, National Invasive Species Information Center, *What is an Invasive Species?*, <http://www.invasivespeciesinfo.gov/whatis.shtml>.

¹³¹ Pimentel, David, Rodolfo Zuniga, Doug Morrison, Update on the environmental and economic costs associated with alien-invasive species in the United States, *Ecological Economics* 52 (2005) 273–288.

¹³² USFS, Pacific Northwest Research Station, *Invasive Species*, <http://www.fs.fed.us/pnw/invasives/index.shtml>.

¹³³ The Council for Agricultural Science and Technology (CAST), 2007, *Biofuel Feedstocks: The Risk of Future Invasions*, CAST Commentary QTA 2007-1, CAST, Ames, IA, <http://www.fs.fed.us/ficmnew/documents/notices/Biofuels2007.pdf>.

¹³⁴ DiTomasco et al., *Biofuels and Invasive Plant Species*, Weed Science Society of America, February 2007, <http://wssa.net/Weeds/Invasive/Reports/index.htm>.

species can compete for or deplete required natural resources, such as water,¹³⁵ reduce livestock forage quality and quantity, jeopardize animal and human health, increase the threat of fire or flooding, interfere with recreational activities, or even lower real estate values. In aquatic ecosystems, weeds can impact the movement and navigation of private and commercial vessels, block irrigation systems, and impede livestock access to water.¹³⁶

Another hazard posed by cultivating invasive bioenergy crops is the potential to spread engineered genetic material and traits. Some energy crops are being genetically modified for advantageous traits, such as drought or salt tolerance and enhanced nutrient use efficiency, which could assist cultivation on marginal lands with less intensive care and inputs. These enhanced environmental tolerances can, however, represent invasive characteristics that enable escape from cultivation and colonization into surrounding ecosystems. Similarly, enhancement of above-ground biomass production via biotechnology could introduce novel traits, such as herbicide resistance,¹³⁷ that enable such cultivars to be more competitive with native vegetation or even other cultivated commodity crops.¹³⁸



Although introducing some proposed feedstock crops may well be safe and beneficial, the ecological, environmental, and economic risks associated with their potential escape and invasion into natural systems must be carefully evaluated along with the agronomic and economic benefits.¹³⁹ Furthermore, increased control and management efforts required to minimize ecosystem, habitat, and species impacts could increase the need for and application of pesticides and herbicides.

¹³⁵ *Arundo donax* is well known and even named for (Arundo are el ladrón de Agua or the water thief) it's extremely high water consumption. In Mexico, streams and rivers go dry as a consequence of heavy infestation of this invasive reed species.

¹³⁶ University of California Agriculture & Natural Resources, *Invasive Plants*, November 2007, Publication 74139, <http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74139.html>.

¹³⁷ Glyphosate resistant *Palmer amaranth*, or pigweed, is an example of a weed species that has potentially adopted an engineered genetic trait commonly inserted into commodity crops, such as corn, soybeans, and cotton. The combination of heavy selection pressure (excessive use of glyphosate) and suspected of cross-hybridization, or transfer, of this genetic trait to pigweed and other weeds is now threatening agricultural crops in a growing number of states across the United States.

¹³⁸ CAST, 2007, *Biofuel Feedstocks: The Risk of Future Invasions*, CAST Commentary QTA 2007-1, CAST, Ames, IA, <http://www.fs.fed.us/ficmnew/documents/notices/Biofuels2007.pdf>.

¹³⁹ DiTomasco et al., *Biofuels and Invasive Plant Species*, Weed Science Society of America, February 2007, <http://wssa.net/Weeds/Invasive/Reports/index.htm>.

RELEVANCE AND RATIONALE

Effective evaluation and management of energy crops with invasive characteristics is essential to ensure sustainable and economical cultivation of biofuel feedstocks. Despite its environmental and economic importance, Table B-100 illustrates the limited attention invasive species are given in biofuel sustainability related statutes. No proposed metrics for this indicator were identified.

Table B-100. Invasive Species Statutory and Policy Relevance

	General relevance	Direct relevance
<i>Statutory and Regulatory Relevance</i>		
Biomass Research and Development Act of 2000		Yes
EISA of 2007		Yes
National Environmental Protection Act of 1970	Yes	
<i>USG Policy Relevance</i>		
EO 13112		Yes

Conversely, Table B-101 suggests that invasive species management is a widespread concern and priority across several biofuel sustainability frameworks, approaches, and industry standards.

Table B-101. Invasive Species in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
EPA, Biofuels and the Environment: First Triennial Report to Congress	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	Yes
CAAFI Environmental Working Group	Yes	
Council on Sustainable Biomass Production	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Invasive species metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics that enable risk management based comparisons among drop-in biofuel feedstock options. At a minimum, the following metrics are required to first determine the invasiveness hazard as posed by a particular feedstock crop; and, second, quantification of the location specific sensitivity to impacts by such invasive species.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: State invasiveness ranking, occasionally/moderately/highly invasive
- ◆ Metric 2: Genetically modified organism (GMO) hazard, Yes/No and Hazard Category
- ◆ Metric 3: Species hybridization propensity, 0–20 Percent

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 4: Appropriate habitat present, Yes/No
- ◆ Metric 5: Local potential for cross-hybridization, Yes/No
- ◆ Metric 6: Critical habitat for threatened and endangered (T&E) species present, Yes/No

Risk Reduction (Mitigation Metrics)

- ◆ Metric 7: Conservation measures or BMPs implemented, Yes/No.

Applicability of invasive potential has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-102 summarizes these applicability findings.

Table B-102. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: State invasiveness ranking	Yes	Minimal	Minimal	No	No
Metric 2: GMO hazard	Yes	Yes	Yes ¹⁴⁰	No	No
Metric 3: Species hybridization propensity	Yes	Minimal	Minimal	No	No
Metric 4: Appropriate habitat present	Yes	Minimal	Minimal	No	No
Metric 5: Local potential for cross-hybridization	Yes	Minimal	Minimal	No	No

¹⁴⁰ The majority of these metrics are only applicable to stages 1 and 2, but new bioreactor-based conversion processes are being developed, some enabled by genetically modified organisms (for example, Lanzatech engineered microbe biocatalysts or Solazyme's heterotrophic micro-algae oil production systems). Such production systems merit further study to understand their risks and, as applicable, their World Health Organization (WHO) Risk Category rating. For additional information, see more at: <http://www.absa.org/riskgroups/index.html>.

Table B-102. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 6: Critical habitat for T&E species present	Yes	Minimal	Yes	No	No
Metric 7: Conservation measures or BMPs implemented	Yes	Minimal	Yes	No	No

MEASUREMENT AND ANALYSIS APPROACH

Metrics 1, 2, and 3 focus on first characterizing the invasiveness characteristics of a feedstock and whether it poses downstream risks in stage 2 or 3. Further, some emerging production, preprocessing, and conversion technologies may utilize GMO microbial or microalgae species across the applicable biofuel life cycles (stages 1–3). The following consequence Metrics 4–6 then focus on three types of sensitivity indicators: 1) vulnerable habitat, 2) presences of wild species susceptible to cross-hybridization, and 3) T&E species that could be impacted, with their resultant legal implications. Metric 7 then focuses on whether applicable conservation measures and BMPs are being applied in a manner that mitigates raw risk score.

Metric 1: State Invasiveness Ranking

Metric 1 focuses on the national and state invasiveness rankings of a feedstock being considered. This metric is mainly determined by the crop type and characteristics but, in the case of state lists, is influenced by the particular state being considered.

Key measurements, databases, and approaches for calculating Metric 1 include:

- ◆ Bureau of Land Management (BLM) National List of Invasive Weed Species of Concern (http://www.blm.gov/co/st/en/BLM_Programs/botany/invasiweed.html).
- ◆ State invasive species resources listed on the USDA National Invasive Species Information Center (<http://www.invasivespeciesinfo.gov/unitedstates/state.shtml>).

For national-level assessment, search the BLM National List of Invasive Weed Species of Concern and determine presence or absence of the proposed bioenergy crop. For regional- or state-level evaluations, refer to the applicable state(s) invasive species lists and capture invasive species ranking, such as occasionally, moderately, or highly invasive. However, in doing so, it is important to note that rankings and their definitions vary by state. Likewise, please note that some novel

invasive feedstocks may not be identified on BLM or state invasive species lists because of the lack of information on these species or their characteristics. In particular, novel species or those with genetically engineered traits should be handled with caution using a precautionary approach until targeted research has been performed and reduced the uncertainty. Once released, it is often costly or impossible to mitigate their spread should they possess invasive characteristics.

Once BLM list presence or state invasive rankings are determined, this qualitative metric is used to evaluate the level of invasiveness hazard. Table B-103 shows hazard thresholds based on invasive rankings of occasionally, moderately and highly invasive. However, these threshold levels should be revised if applicable state rankings diverges (e.g., Texas ranks their invasive species as severe, moderate, limited, none, and unknown). When unknown, they should be ranked as a hazard of the highest level, again reflecting a precautionary approach.

Table B-103. State Invasiveness Ranking Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Feedstock has been evaluated but not present on relevant state invasive species list.
Moderate	3	Feedstock is identified as an occasionally invasive species on relevant state invasive species list or unknown.
High	4	Feedstock is identified as a moderately invasive species on relevant state invasive species list.
Highest	5	Feedstock is present on the BLM national list identified as a highly invasive species, on a relevant state invasive species list, or is novel with unknown or uncertain characteristics.

Metric 2: GMO Hazard

Metric 2 focuses on whether the feedstock being analyzed is a GMO, particularly when the introduced traits are novel or evaluated as a hazard.

Key measurements, databases, and approaches for calculating Metric 2 include:

- ◆ Seed provider or feedstock producer supplied information.
- ◆ American Biological Safety Association (ABSA), WHO Risk Group Category, Risk Group Database (<http://www.absa.org/riskgroups/index.html>)

Determine whether the feedstock has been genetically modified. The seed provider or feedstock producer should be able to provide this information. If the feedstock is a GMO, the seed provider should also be able to provide a risk assessment for the cultivar or WHO Risk Category for microorganisms. Once it is determined whether the feedstock is a GMO and the relevant risk assessment has been reviewed, Table B-104 defines hazard thresholds to evaluate the invasiveness likelihood of hazard.

Table B-104. GMO Hazard Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	The feedstock has not been genetically modified and is a WHO Risk Group 1
Low	2	The feedstock is a GMO and is a WHO Risk Group 1
Moderate	3	The feedstock is a GMO, but the risk assessments show a minimal level of risk and/or is a WHO Risk Group 2
High	4	The feedstock is a GMO, and the risk assessments show a moderate level of risk and/or is a WHO Risk Group 3
Highest	5	The feedstock is a GMO and the risk assessments show a high level of invasiveness risk, is a WHO Risk Group 4, or has no risk assessment available.

Metric 3: Species Hybridization Propensity

Metric 3 evaluates the ability of a bioenergy crop's pollen to hybridize with other species, genus, or even other families. This hazard metric is largely determined by the crop family, genus, and species. Gene flow between cultivated plants and wild relatives is a concern because crop alleles may inadvertently transfer and persist in wild populations. Such transfers may dilute the native gene pool or confer traits that enhance lifetime fitness, which could increase the wild populations' characteristics or tendency toward weediness.¹⁴¹ In short, invasive plants can potentially fertilize closely related indigenous plants via cross-hybridization and creating aggressive weeds or invasive species derivatives.

Key measurements, databases, and approaches for calculating Metric 3 include:

- ◆ Crop hybridization propensities, 0–20 scale.

Hybridization propensities have been defined for numerous crop families by Whitney et al. 2010.¹⁴² This scale represents weighted percentage averages of all possible hybrid combinations within specific genera. In evaluating a feedstock crop, its family should be compared against those presented in Whitney et al. and its associated hybridization propensity should be determined.

Once classified, Table B-105 defines hazard thresholds to evaluate the cross-hybridization hazard likelihood. These thresholds are based upon the natural breaks presented in Figure 2 and 3 of Whitney et al. 2010.

¹⁴¹ Sottlemeyer, Amy Louise, *Investigating the Hybridization Potential, Components of Fitness and Volunteerism in Wild and Cultivated Panicum virgatum L. Dissertation*, The Ohio State University, 2012, http://etd.ohiolink.edu/view.cgi?acc_num=osu1331060664.

¹⁴² Whitney et al., "Patterns of hybridization in plants," *Perspectives in Plant Ecology, Evolution and Systematics*, 12 (2010) 175–182.

Table B-105. Hybridization Propensity Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	<0.1
Low	2	0.1—0.5
Moderate	3	0.6—1
High	4	1.1—2
Highest	5	>2

Metric 4: Appropriate Habitat Present

Metric 4 is oriented on whether the habitat at and near crop cultivation locations are aligned with invasive species habitat requirements. If so, these compatible habitats may increase the possibility that the invasive species could escape from cultivation and generate ecosystem impacts. This consequent metric is highly dependent upon local habitat type.

Key measurements, databases, and approaches for calculating Metric 4 include:

- ◆ Habitat descriptions provided in state invasive species websites or databases (e.g., <http://www.texasinvasives.org>).
- ◆ USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>).
- ◆ Topographic maps (<http://www.topozone.com/>).

Habitat requirements for invasive species can be found on most state invasive species web portals. Once the habitat requirements for a particular invasive species are identified, evaluate whether the habitat requirements are met at or near crop cultivation location(s) using the USDA NRCS WSS and topographic maps.

After making these determinations, apply the thresholds presented in Table B-106 and determine the resultant consequence rating. For example, Carrizo cane (*Arundo donax*) is considered to be a moderately invasive plant by the state of Texas with severe impacts.¹⁴³ Habitat requirements for *Arundo donax* include moist places such as ditches, streams, and riverbanks, and it grows best in well drained soils where abundant moisture is available. Therefore, if the crop cultivation locales do not include this type of habitat, then this feedstock would receive a lower consequence assessment for this metric.

¹⁴³ http://www.texasinvasives.org/professionals/assessment_detail.php?symbol=ARDO4.

Table B-106. Appropriate Habitat Present Thresholds

Likelihood of impact	Assessed value	Threshold
Lowest	1	Feedstock is not on applicable state invasive species lists.
Low	2	Feedstock is on relevant state invasive species list, but crop cultivation locale does not meet habitat requirements.
Moderate	3	Feedstock is on relevant state invasive species list, and crop cultivation locale potentially aligned with habitat requirements.
High	4	Feedstock is on relevant state invasive species list, and crop cultivation locale moderately aligned with habitat requirements.
Highest	5	Feedstock is on relevant state invasive species list, and crop cultivation locale highly aligned with habitat requirements.

Metric 5: Local Potential for Cross-Hybridization

Metric 5 focuses on whether there are closely or distantly related plants present near crop cultivation locations that the proposed biofuel feedstock crop could cross-hybridize with if given the opportunity. This metric is driven by the crop type and cultivation location(s).

Key measurements, databases, and approaches for calculating Metric 5 include:

- ◆ USDA PLANTS Database (<http://plants.usda.gov/java/>).

Plants are most likely to hybridize within their genus. The USDA PLANTS Database can be used to identify the geographic distribution of a biofuel feedstock genus. Therefore, once crop cultivation location is identified, its proximity to the geographic distribution of the biofuel crop genus can be quickly assessed. This screening can identify susceptibility toward unintended cross-hybridization.

After making this determination, these results are applied to thresholds presented in Table B-107 and used to determine the resulting consequence rating.

Table B-107. Local Sensitivity for Hybridization Thresholds

Likelihood of impact	Assessed value	Threshold
Lowest	1	Crop cultivation location(s) is not located within the geographic distribution of feedstock genus.
Moderate	3	Crop cultivation location(s) is located on the border of the geographic distribution of feedstock genus.
Highest	5	Crop cultivation location(s) is located within geographic distribution of feedstock genus.

Metric 6: Critical Habitat for T&E Species Present

Metric 6 focuses on whether critical habitat for T&E species is present near crop cultivation locations, particularly those that could be impacted by invasive species. This metric is focused on the local habitat that supports these T&E species. Critical habitat is a term defined by and used in the Endangered Species Act. It is a specific geographic area(s) essential for the conservation of a T&E species and may require special management and protection. Critical habitat may also include an area that is not currently occupied by the species but is needed for its recovery.¹⁴⁴ Bioenergy feedstock crops cultivated on lands surrounded by sensitive lands, such as wildlife refuges or T&E species habitat, could represent impact sensitivity should the cultivar species escape cultivation and impact these legally protected areas.

Key measurements, databases, and approaches for calculating Metric 6 include:

- ◆ USFWS Information, Planning, and Conservation (IPaC) System (<http://ecos.fws.gov/ipac/>).
- ◆ USFWS Critical Habitat Portal (<http://criticalhabitat.fws.gov/crithab/>).
- ◆ State agency responsible for administration of state T&E programs and/or natural resource protection.

Determine whether critical habitat for T&E species is present within 0.5-mile of crop cultivation locations through either the USFWS IPaC website, the USFWS Critical Habitat Portal, or through state agencies responsible for T&E program oversight and/or natural resource protection. Some states may have analogous websites, similar to IPaC, that allow the user to identify whether a designated critical habitat may be affected by a proposed project. However, in some states, the local state office will need to be contacted directly.

Once local critical habitats are identified, it is necessary to evaluate whether they would be sensitive to the cultivation of a proposed biofuel crop. Table B-108 presents assessment thresholds and should be used in determining the appropriate consequence rating.

Table B-108. Local Sensitive Habitats Thresholds

Likelihood of impact	Assessed value	Threshold
Lowest	1	Critical habitat for T&E species is not present within 0.5-mile of crop cultivation location(s).
Moderate	3	Critical habitat for T&E species is present within 0.5-mile of crop cultivation location(s) but not directly adjacent.

¹⁴⁴ USFWS, *Critical Habitat: What is it?*, February 2002, http://www.fs.fed.us/r9/wildlife/tes/docs/esa_references/critical_habitat.pdf.

Table B-108. Local Sensitive Habitats Thresholds

Likelihood of impact	Assessed value	Threshold
Highest	5	Critical habitat for T&E species present on, directly adjacent to, downstream from, or within the air shed of crop cultivation location(s), as applicable.

Metric 7: Conservation Measures or BMPs Implemented

Metric 7 addresses the applicable conservation or BMP risk mitigation measures used to reduce invasive species raw risks ratings. While primarily applicable to stage 1, such mitigations may also be relevant to stages 2 and 3.

Key measurements, databases, and tools for calculating Metric 7 include:

- ◆ USFWS IPaC System (<http://ecos.fws.gov/ipac/>).
- ◆ Consultations with USFWS and state agencies responsible for administration of T&E species programs and/or natural resource protection.

The USFWS IPaC System and/or consultations with USFWS and state agencies should identify conservation measures or BMPs that can reduce invasive species risks, such as the use of sterile cultivars. Feedstock producers that consult with USFWS and state agencies and apply such measures will realize a reduction of their likelihood metric(s). The specific mitigation applied would determine the amount of adjustment applied to the likelihood of hazard ratings in Metrics 1–3, which would be used to calculate mitigated risk scores.

General Considerations, Assumptions, and Uncertainties

The proposed metrics were developed as a representative but simple means to estimate invasiveness potential, consequences, and mitigation of biomass cultivation and its respective biofuel production pathways. The listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and research gaps associated with species characteristics, data availability, and variations in state invasive species programs will arise, particularly for emerging energy crops with less available research results.

RESOURCES, SMES, AND CAPABILITIES

Keystone Resources

BLM National List of Invasive Weed Species of Concern
(http://www.blm.gov/co/st/en/BLM_Programs/botany/invasiweed.html)

USDA NRCS WSS (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>)

Topozone, topographic maps (<http://www.topozone.com/>)

USDA PLANTS Database (<http://plants.usda.gov/java/>)

USFWS IPaC System (<http://ecos.fws.gov/ipac/>)

USFWS Critical Habitat Portal (<http://criticalhabitat.fws.gov/crithab/>)

Identified SMEs and Organizations

John Goolsby, USDA

Frank Reilly, LMI

USDA, National Invasive Species Information Center
(<http://www.invasivespeciesinfo.gov/>)

Supplementary Supporting Capabilities

More detailed regional and local analysis for each feedstock cultivar or genotype's invasive potential and the local sensitivity to ecological impacts can be supported with the following capabilities:

- ◆ Weed Risk Assessment (WRA) evaluations—protocols based on target species biology, ecology, climatic requirements, and introduction history—of each potential genotype targeted for cultivation within a particular region (http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/riskassessments.shtml).
- ◆ Climate-matching analysis to determine regions of agronomic suitability and identification of regions climatically suitable to a potential invasion.
- ◆ Determination of the susceptibility of native and managed ecosystems to introduction of seeds or vegetative fragments of the biofuel feedstock.
- ◆ Multiyear studies of competitive interactions between biofuel crops and native or agronomic species within susceptible ecosystems.
- ◆ Establishment of pre-introductory management protocols that demonstrate eradication of proposed feedstocks.¹⁴⁵

¹⁴⁵ CAST, 2007, *Biofuel Feedstocks: The Risk of Future Invasions*, CAST Commentary QTA 2007-1, CAST, Ames, IA, <http://www.fs.fed.us/ficmnew/documents/notices/Biofuels2007.pdf>.

REFERENCES

- CAST, 2007, *Biofuel Feedstocks: The Risk of Future Invasions*, CAST Commentary QTA 2007-1, CAST, Ames, IA, <http://www.fs.fed.us/ficmnew/documents/notices/Biofuels2007.pdf>.
- DiTomasco, Joe, Jodie Holt, Nelroy Jackson, *Biofuels and Invasive Plant Species*, Weed Science Society of America, February 2007, <http://wssa.net/Weeds/Invasive/Reports/index.htm>.
- Pimentel, David, Rodolfo Zuniga, Doug Morrison, *Update on the environmental and economic costs associated with alien-invasive species in the United States*, *Ecological Economics*, 52 (2005) 273–288.
- Sottlemeyer, Amy Louise, *Investigating the Hybridization Potential, Components of Fitness and Volunteerism in Wild and Cultivated *Panicum virgatum* L.* Dissertation, The Ohio State University, 2012, http://etd.ohiolink.edu/view.cgi?acc_num=osu1331060664.
- USDA, National Invasive Species Information Center, *What is an Invasive Species?*, <http://www.invasivespeciesinfo.gov/whatis.shtml>.
- USFS, Pacific Northwest Research Station, *Invasive Species*, <http://www.fs.fed.us/pnw/invasives/index.shtml>.
- Whitney, Kenneth D, Jeffrey R. Ahern, Lesley G. Campbell, Loren P. Albert, Matthew S. King, “Patterns of hybridization in plants,” *Perspectives in Plant Ecology, Evolution and Systematics*, 12 (2010) 175–182.

Direct Food Security

Pillar	Social
Criteria	Food Security
Indicator	Direct Food Security

With one billion people worldwide unable to access nutritious foods on a regular basis, using food crops for biofuels has brought food security to the forefront as an increasingly important issue.¹⁴⁶ According to the WHO, “food security is built on three pillars”

- ◆ *Food availability, having nutritious food available on a consistent basis*
- ◆ *Food access, having nutritious food resources readily available for use*
- ◆ *Food use, having a balanced diet, in addition to water and sanitation*¹⁴⁷

The USDA suggests that food security is

- ◆ *The ready availability of nutritionally adequate and safe foods.*
- ◆ *Assured ability to acquire acceptable foods in socially acceptable ways (that is, without resorting to emergency food supplies, scavenging, stealing, or other coping strategies).*¹⁴⁸

US government mandates for renewable fuel production have also strongly promoted and incentivized the use of readily available agricultural crops for fuel, such as corn.¹⁴⁹ This has, however, raised a sometimes heated debate centered on the food security implications of biofuel production. On one hand, the expanded production of biofuel crops results can increase job creation and household income in rural areas, increase the *ability to acquire* food. It can also have the effect of increased food production and supply, depending on the co-products generated, and has the effect of driving down food costs. The other side of the debate is that biofuel production diverts food crops (increased demand) and

¹⁴⁶ USDA, *USDA Accomplishments 2009–2011: Global Food Security*, <http://www.usda.gov/documents/Results-Global-Food-Security.pdf>.

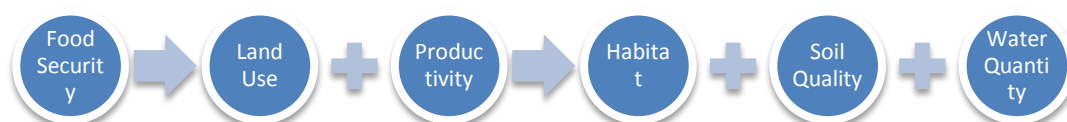
¹⁴⁷ WHO, Food Security, Trade, foreign policy, diplomacy and health, <http://www.who.int/trade/glossary/story028/en/>.

¹⁴⁸ USDA, ERS, *Food Security in the US*, <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement.aspx>. From: Andersen, S.A. ed., Core Indicators of Nutritional State for Difficult to Sample Populations, *The Journal of Nutrition* 120:1557S-1600S, 1990.

¹⁴⁹ The Freeman Spogli Institute for International Studies at Stanford University, *Biofuels have mixed impacts on food security*, Kate Johnson, April 19, 2012, http://fsi.stanford.edu/news/biofuels_have_mixed_impacts_on_food_security_20120419/.

feedstock cultivation can displace food production (reduced supply), which can both potentially increase US and global food prices, which can negatively impact *food access and use*.¹⁵⁰ Biofuel production is also indirectly linked with food security, as increased crop production for biofuels increases demand for agricultural inputs such as fertilizer, pesticides, and water, which also raise the price of inputs required for food crop production.

Classifying direct and indirect food security indicators is useful for framing the analysis. For the purposes of this indicator, we focus on direct food security metrics that are oriented on US domestic market, communities, and citizens. Global implications would constitute indirect food security and is not addressed.



Food security interacts with and influences many other indicators. For example, the desire to keep existing agricultural fields under food crop cultivation could influence feedstock producers to bring Conservation Reserve Program land back into production. Likewise, increased pressures to increase land productivity could result in increased use of inputs and cultivation intensity. These both could result in habitat alterations, soil erosion, and water quality impacts.

RELEVANCE AND RATIONALE

Food security was selected as an indicator, as robust analysis and management will support sustainable selection and cultivation of bioenergy feedstocks. Table B-109 highlights statutes where food security has direct relevance.

Table B-109. Food Security Statutory Relevance

	General relevance	Direct relevance
Statutory and Regulatory Relevance		
EISA of 2007		Yes
Food, Conservation, and Energy Act of 2008		Yes

Interest in food security is widespread, with indicators appearing in virtually every biofuel sustainability framework, approach, and industry standard (Table B-110).

¹⁵⁰ GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

Table B-110. Food Security in Sustainability Frameworks and Standards

	Indicator	Proposes metric(s)
MOU between US Navy, DOE, and USDA	Yes	
ORNL, Center for BioEnergy Sustainability	Yes	
USDA Biofuel Sustainability Assessment Framework	Yes	Yes
CAAFI Environmental Working Group	Yes	
GBEP	Yes	
Roundtable on Sustainable Biofuels	Yes	Yes

METRICS SELECTED

Food security metrics have been identified and selected to reflect the feedstock and conversion pathway characteristics applicable for meaningful comparisons among drop-in biofuel supply chains. At a minimum, the following metrics are required to first determine the food security hazard posed by a particular feedstock crop and cultivation system; and, second, the assessment of local or regional sensitivities for food security.

Pathway Characteristics (Likelihood Metrics)

- ◆ Metric 1: Feedstock is a food source, Yes/No

Regional or Site Assessment Sensitivity (Consequence Metrics)

- ◆ Metric 2: Food or feed crop displacement, Yes/No
- ◆ Metric 3: Food insecurity status of local population,¹⁵¹ percentage

Risk Reduction (Mitigation Metrics)

- ◆ Metric 4: Feedstock production increases food supply, Yes/No

The applicability of food security metrics has been reviewed for each biofuel life-cycle step and evaluated for applicability. Table B-111 summarizes these applicability findings.

¹⁵¹USDA, *Food Security in the U.S.*, <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement.aspx>.

Table B-111. Metric Relevance by Life-cycle Stage

Life-cycle stage	Stage # 1– feedstock acquisition	Stage # 2– processing and logistics	Stage # 3– biofuel production	Stage # 4– biofuel distribution	Stage # 5– biofuel use
Metric 1: Feedstock is a food source	Yes	No	No	No	No
Metric 2: Food or feed crop displacement	Yes	No	No	No	No
Metric 3: Food insecurity status of local population	Yes	No	No	No	No
Metric 4: Feedstock production increases food supply	Yes	No	No	No	No

MEASUREMENT AND ANALYSIS APPROACH

Metrics 1 focuses on first characterizing the food security hazards from feedstocks. Metrics 2 and 3 are consequence metrics that characterize the local or regional susceptibility or sensitivity to food security impacts. Finally, Metric 4 focuses on whether the production of a biofuel feedstock has the potential to increase the domestic supply of food and mitigates its raw likelihood of hazard and risk score.

Metric 1: Feedstock is a Food Source

Metric 1 focuses on whether the biofuel feedstock is considered a food crop. Food crops refer to agricultural products that are directly used for human consumption (as food) or for livestock consumption (as feed).

Key measurements, databases, and tools for calculating Metric 1 include:

- ◆ USDA ARS and ERS, Food Intakes Converted to Retail Commodities 2001-2002 Data Tables (<http://www.ars.usda.gov/Services/docs.htm?docid=21992>)

USDAs ARS and ERS generate data tables that include national estimates of the amounts of retail-level commodities that are consumed per person based on food intake data, as recorded in national dietary surveys.¹⁵² Retail-level commodities are defined as those available for purchase in retail stores, supermarkets, or other retail food outlets with a few exceptions such as industrial shortening and corn syrup solids, which are solely used by the food industry, and wild game meats

¹⁵²USDA ARS and ERS, *Retail Food Commodity Intakes: Mean Amounts of Retail Commodities per Individual, 2001–2002*, Bowman, Shanthy A; Martin, Carrie, L; Friday, James E; Clemens, John; Moshfegh, Alanna J; Lin, Biing-Hwan; Wells, Hodan F. 2011, <http://www.ars.usda.gov/Services/docs.htm?docid=21992>.

obtained elsewhere. These commodities are grouped into eight major categories: dairy products; fats and oils; fruits; grains; meat, poultry, fish and eggs; nuts; caloric sweeteners; and vegetables, dry beans, and legumes. The surveyed foods are further broken down into a total of 65 retail-level commodities. Appendix A of *Retail Food Commodity Intakes: Mean Amounts of Retail Commodities per Individual, 2001–2002*¹⁵³ provides a complete list of foods within these commodity categories.

Crops are also used to feed livestock and, thus, are indirectly used for human food consumption. These crops typically include feed grains (wheat, rice, corn, grain sorghum, barley, and oats), foreign coarse grains (feed grains plus rye, millet, and mixed grains), hay, and related items. Feed crops may also include oilseed crops, which are seeds high in oil and protein. A commonly grown oilseed crop for animal feed is soybean.¹⁵⁴

Using the retail-level food commodities categories and livestock feed crop data, we evaluate the likelihood of hazard associated with whether a biofuel feedstock is a food source, using the thresholds presented in Table B-112.

Table B-112. Food Crops Used as Feedstocks Thresholds

Likelihood of hazard	Assessed value	Threshold
Lowest	1	Feedstock or byproduct is not commonly used as human food source or as a source of livestock feed
Low	2	Feedstock is a used as livestock feed or product
Moderate	3	Feedstock is commonly used for food, feed or product purposes
High	4	Feedstock is or derived from a non-edible grade of human food source
Highest	5	Feedstock or byproduct is solely used as a human food source

Metric 2: Food or Feed Crop Displacement

Metric 2 assesses whether regional or local land need to produce biofuel feedstocks is taking food or feed crops out of production. This consequence metric is needed to understand the crops already grown in the region or locality.

Key measurements, databases, and tools for calculating Metric 2 include:

◆ Biofuel feedstock producer

¹⁵³ USDA ARS and ERS, *Retail Food Commodity Intakes: Mean Amounts of Retail Commodities per Individual, 2001–2002*, Bowman, Shanthi A; Martin, Carrie, L; Friday, James E; Clemens, John; Moshfegh, Alanna J; Lin, Biing-Hwan; Wells, Hodan F. 2011, <http://www.ars.usda.gov/Services/docs.htm?docid=21992>.

¹⁵⁴ American Society of Agronomy, *About Agronomy: Feed Crops*, <https://www.agronomy.org/about-agronomy/feed-crops>.

- ◆ USDA Local Farm Service Agency (FSA)
(<http://offices.sc.egov.usda.gov/locator/app>).

Once crop cultivation location(s) is identified, contact the biofuel feedstock producer or the local USDA FSA to determine what crops are typically grown on or around the proposed biofuel crop cultivation location. This information can be used to determine whether biofuel feedstock production would be taking land out of production for food or feed. Apply these findings against the thresholds presented in Table B-113 to determine the consequence rating.

Table B-113. Feedstock Production on Land for Food Production Thresholds

Consequence of hazard	Assessed value	Threshold
Lowest	1	Food or feed crops are not typically grown on feedstock production site
Moderate	3	Food or feed crops are grown in the county of the proposed feedstock production site, but have not been grown specifically on the biofuel feedstock production site
Highest	5	Food or feed crops have historically been grown on the biofuel feedstock production site

Metric 3: Food Insecurity Status of Local Population

As a consequence metric, Metric 3 assesses the food insecurity status of the local population. In the United States, a population is classified as having food insecurity when they have “limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways.”¹⁵⁵ USDA ERS, via the Census Bureau for the Bureau of Labor Statistics, surveys and assesses food security within the United States.

Key measurements, databases, and tools for calculating Metric 3 include:

- ◆ USDA, ERS, Food Environment Atlas (<http://www.ers.usda.gov/data-products/food-environment-atlas/go-to-the-atlas.aspx>).

Once crop cultivation location(s) is identified, USDA’s Food Environment Atlas can be used to identify what percentage of households in the local population have food insecurity. When accessing the Food Environment Atlas, display the household food insecurity map for the most recent year(s) available. Once the food insecurity status percentage is determined, apply these findings against the thresholds presented in Table B-114 to determine the resultant consequence rating.

¹⁵⁵ USDA, ERS, *Food Security in the US*, <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement.aspx>. From: Andersen, S.A. ed., Core Indicators of Nutritional State for Difficult to Sample Populations, *The Journal of Nutrition* 120:1557S-1600S, 1990.

Table B-114. Food Insecurity Thresholds

Consequence of hazard	Assessed value	Threshold
Lowest	1	≤10 percent of households
Moderate	3	10.1–13 percent of households
Highest	5	>13 percent of households

Metric 4: Feedstock Production Increases Food Supply

Metric 4 is a mitigation measure that addresses whether increased production of a biofuel feedstock will also directly expand the local food supply. Some parties express concern about food crop use as biofuel feedstock and the direct reduction of food supplies and resultant increase in prices. However, increased production of certain biofuel feedstocks, such as soybean oil, can contribute to expanded co-product production, such as soybean meal, and domestic supply, which can be used for food, feed, fiber, or export.¹⁵⁶ For example, biofuel feedstock demand increases the production of soybeans and soybean oil; however, the soy meal co-product, a high protein food source, supply is greatly expanded for use as food or feed. As feedstock oil production is increased, this could expand the supply of co-product produced, expand this food product's supply, and reduce its cost. The intent of this mitigation metric is to determine if co-product is a food or feed product, and reassessment of Metrics 1 likelihood rating. This new hazard rating would then adjust the indicator's raw risk score.

General Considerations, Assumptions, and Uncertainties

The proposed metrics were developed as a representative but simple means to estimate direct food security risks, particularly relevant to biomass feedstock cultivation. As such, the listed resources and tools are not intended to be comprehensive and additional data sources may be required to augment the analysis needed for complete coverage of this indicator. Limitations and gaps associated with data availability and reporting will likely arise, particularly for emerging energy crops where little data is yet available.

RESOURCES

Keystone Resources

USDA, ARS, Food Intakes Converted to Retail Commodities Data Tables
(<http://www.ars.usda.gov/Services/docs.htm?docid=21992>)

¹⁵⁶ GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

USDA, Local FSAs (<http://offices.sc.egov.usda.gov/locator/app>)

USDA, ERS, Food Environment Atlas (<http://www.ers.usda.gov/data-products/food-environment-atlas/go-to-the-atlas.aspx>)

REFERENCES

American Society of Agronomy, *About Agronomy: Feed Crops*,
<https://www.agronomy.org/about-agronomy/feed-crops>.

The Freeman Spogli Institute for International Studies at Stanford University,
Biofuels have mixed impacts on food security, Kate Johnson, April 19, 2012,
http://fsi.stanford.edu/news/biofuels_have_mixed_impacts_on_food_security_20120419/.

GBEP, *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*, First Edition, December 2011, http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/Report_21_December.pdf.

USDA ARS and ERS, *Retail Food Commodity Intakes: Mean Amounts of Retail Commodities per Individual, 2001-2002*, Bowman, Shanthy A; Martin, Carrie, L; Friday, James E; Clemens, John; Moshfegh, Alanna J; Lin, Biing-Hwan; Wells, Hodan F. 2011, <http://www.ars.usda.gov/Services/docs.htm?docid=21992>.

USDA, Definitions of Food Security, <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx>.

USDA, *Food Security in the US*, <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement.aspx>.

USDA, *USDA Accomplishments 2009–2011: Global Food Security*,
<http://www.usda.gov/documents/Results-Global-Food-Security.pdf>.

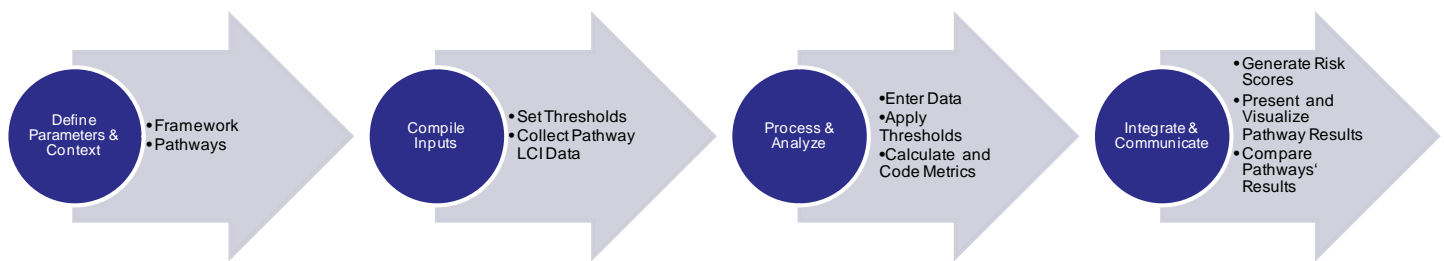
Appendix C

Sustainability Assessment Example

The third component of the proposed biofuel sustainability architecture is the sustainability assessment. This process is intended to build on the biofuel sustainability framework and the pathway snapshots to robustly quantify, integrate, analyze, display individual pathway's detailed assessed risk ratings, and compare different pathways' summary scores at the risk, indicator, and criteria levels.

Figure C-1 summarizes the sustainability assessment process.

Figure C-1. Sustainability Assessment Process



The draft sustainability assessment analysis workbook was developed to integrate these four components and their respective steps. Soybean oil HEFA fuel pathway was studied and used as an example to develop several indicator analysis modules and feed into a detailed results worksheet. Preliminary waste oil HEFA and camelina HEFA example data sets and metric ratings were integrated into the comparative risk results worksheets and graphic displays to demonstrate the risk score based outputs of this sustainability assessment process. Figure C-2 thru C-9 are provided to demonstrate this process and example analysis developed in the draft sustainability workbook.

Please note that all results displayed are preliminary and only intended to illustrate the sustainability assessment process. All metric ratings and risk scores generated require further research, vetting with technical SMEs, and quality control checks prior to their citation or use.

Figure C-2. Biofuel Sustainability Framework

Microsoft Excel - DLA_Energy_Sust_Assessment_Draft_120612.xlsx									
	A	B	C	E	F	G	H	I	J
1	Org/Title:	DLA Energy Biofuels Study							
2	Source:	LMI							
3	Area of Focus:	Feedstock, Production, and Biofuel Use							
4									
5									
6	Sustainability Pillar	Criteria	Indicators	Sustainability Assessment	DLA Applicab	Statute	USG Policy	DoD Policy	Sust Frameworks / Standard
7	Operational Sustainability	Suitability	Fuel Readiness Level	Yes	High	⊗ 1	⊗ 0	⊗ 2	⊗ 0
8	Operational Sustainability	Suitability	ASTM Spec Met	Yes	High	⊕ 2	⊗ 0	⊗ 0	⊗ 2
9	Operational Sustainability	Suitability	Operational Fuel Spec Met	Yes	High	⊗ 0	⊗ 0	⊗ 0	⊗ 2
11	Operational Sustainability	Energy Security	Energy Diversity	Yes	High	⊕ 5	⊕ 5	⊕ 5	⊕ 5
14	Operational Sustainability	Availability	Feedstock Readiness Level	Yes	High	⊕ 2	⊗ 0	⊗ 0	⊗ 1
26	Economic Sustainability	Economic Viability	Cost / Price	Yes	High	⊕ 2	⊗ 0	⊗ 1	⊗ 3
30	Environmental Sustainability	Water	Water Quantity	Yes	High	⊕ 5	⊕ 6	⊕ 7	⊕ 9
31	Environmental Sustainability	Water	Water Quality	Yes	High	⊕ 4	⊕ 6	⊕ 6	⊕ 10
35	Environmental Sustainability	Air	Air Quality	Yes	High	⊕ 2	⊕ 4	⊕ 4	⊕ 10
36	Environmental Sustainability	Air	Ozone Depletion	Yes	High	⊗ 1	⊗ 3	⊗ 3	⊗ 3
37	Environmental Sustainability	Air	GHG - Direct Emissions	Yes	High	⊕ 4	⊕ 7	⊕ 7	⊕ 10
39	Environmental Sustainability	Land Use	Land Use - Direct	Yes	High	⊕ 3	⊗ 2	⊗ 2	⊕ 8
42	Environmental Sustainability	Soil	Soil Quality	Yes	High	⊕ 4	⊗ 1	⊗ 1	⊕ 9
43	Environmental Sustainability	Soil	Soil Quantity	Yes	High	⊕ 5	⊗ 1	⊗ 1	⊕ 6
45	Environmental Sustainability	Productivity	Nutrient Requirements / Fertilizer Use	Yes	High	⊕ 2	⊗ 1	⊗ 1	⊗ 2
46	Environmental Sustainability	Productivity	Pesticides Use / Management Practice	Yes	High	⊗ 1	⊗ 3	⊗ 3	⊗ 2
53	Environmental Sustainability	Biological Resources	Invasive Species	Yes	High	⊕ 2	⊗ 1	⊗ 1	⊕ 6
64	Social Sustainability	Food Security	Food Security	Yes	High	⊕ 2	⊗ 0	⊗ 0	⊕ 7
84									
85									

Figure C-3. Feedstock and Conversion Pathways Assessed

Feedstock and Conversion Pathways Assessed													
Pathway_Name	Feedstock_Code	Feedstock_Category	Pre-Processing	Product	Intermediate Processing	Intermediate Product	Processing	Product	Production	Neat Product	Blending	Final Fuel	Fuel Category
Waste Oil HEFA	Process_Waste_Oil	Fats/Grease	N/A	N/A	N/A	N/A	Hydroprocessing	Bio Crude	Fractionation	Bio-SPK	50/50 blend of Bio-SPK and Jet A or diesel fuel (plus additives)	HRJ, HRJ-5, HRJ-8, or HRF-76	Hydrotreated Renewable J (HRJ) or (Marine) Dies Fuel
Soybean Oil HEFA	Ag_Food_Oil	Food Crops (Oil)	Oil Extraction	Oils (Triglycerides)	N/A	N/A	Hydroprocessing	Bio Crude	Fractionation	Bio-SPK	50/50 blend of Bio-SPK and Jet A or diesel fuel (plus additives)	HRJ, HRJ-5, HRJ-8, or HRF-76	Hydrotreated Renewable J (HRJ) or (Marine) Dies Fuel
Camelina Oil HEFA	Ag_Energy_Crop_Oil	Energy Crops	Oil Extraction	Oils (Triglycerides)	N/A	N/A	Hydroprocessing	Bio Crude	Fractionation	Bio-SPK	50/50 blend of Bio-SPK and Jet A or diesel fuel (plus additives)	HRJ, HRJ-5, HRJ-8, or HRF-76	Hydrotreated Renewable J (HRJ) or (Marine) Dies Fuel

Figure C-4. Metric Risk Rating Threshold Levels

Metric Risk Rating Thresholds												
Metric	Metric Code	R_1_Bre	R_1_Thresh	R_2_Bre	R_2_Thresh	R_3_Bre	R_3_Thresh	R_4_Bre	R_4_Thresh	R_5_Bre	R_5_Thresh	
Net Energy Return on Inv	OP-ES-DIV-L01	≤	0.777700469	≤	1.180122108	≤	1.582543747	≤	1.984965386	>	1.984965386	
Fossil Depletion	OP-ES-DIV-L02	≤	0.2	≤	0.4	≤	0.6	≤	0.8	>	0.8	
Petroleum Reliance	OP-ES-DIV-L03	≤	0.2	≤	0.4	≤	0.6	≤	0.8	>	0.8	
Coal Reliance	OP-ES-DIV-L04	≤	0.2	≤	0.4	≤	0.6	≤	0.8	>	0.8	
Natural Gas Reliance	OP-ES-DIV-L05	≤	0.2	≤	0.4	≤	0.6	≤	0.8	>	0.8	
Renewable Quotient	OP-ES-DIV-L06	≥	0.8	≥	0.6	≥	0.4	≥	0.2	<	0.2	
Energy Diversity Index	OP-ES-DIV-L07	≥	0.8	≥	0.6	≥	0.4	≥	0.2	<	0.2	
CO Total Emissions	ENV-AIR-AQ-L01	≤	5.143450153	≤	35.55689454	≤	111.8141338	≤	188.071373	>	188.071373	
SOx Total Emissions	ENV-AIR-AQ-L02	≤	2.96101873	≤	20.46965122	≤	64.36997238	≤	108.2702935	>	108.2702935	
NOx Total Emissions	ENV-AIR-AQ-L03	≤	19.77013047	≤	136.6717715	≤	429.785445	≤	722.8991184	>	722.8991184	
PM2.5 Total Emissions	ENV-AIR-AQ-L04	≤	0.393637076	≤	2.72123022	≤	8.557327737	≤	14.39342525	>	14.39342525	
PM10 Total Emissions	ENV-AIR-AQ-L05	≤	0.548372285	≤	3.790921448	≤	11.92113663	≤	20.05135181	>	20.05135181	
VOCs Total Emissions	ENV-AIR-AQ-L06	≤	1.002113482	≤	6.927654071	≤	21.7850757	≤	36.64249732	>	36.64249732	
CO Non-Attainment Area	ENV-AIR-AQ-C07	≤	0	<	0	<	0	<	0	≥	0	
SOx Non-Attainment Area	ENV-AIR-AQ-C08	≥	0	>	0	>	0	>	0	≤	0	
NOx Non-Attainment Area	ENV-AIR-AQ-C09	>	0	>	0	>	0	>	0	≤	0	
PM2.5 Non-Attainment Area	ENV-AIR-AQ-C10	≥	0	>	0	>	0	>	0	≤	0	
PM10 Non-Attainment Area	ENV-AIR-AQ-C11	≤	0	<	0	<	0	<	0	≥	0	
VOCs NESHAP Area	ENV-AIR-AQ-C12	≥	0	>	0	>	0	>	0	≤	0	
Direct Emissions	ENV-AIR-GHG-L01	≤	17583.5069	≤	43958.76726	≤	70334.02761	≤	87917.53452	>	87917.53452	
Biogenic CO2 Direct Emi	ENV-AIR-GHG-L02	>	0.8	>	0.6	>	0.4	>	0.2	≤	0.2	
Indirect Land Use (ILUC)	ENV-AIR-GHG-L03	≥	0.6	>	0.5	>	0.2	>	0	≤	0	
GHG Intensity Section 52	ENV-AIR-GHG-L04	≤	0.4	<	0.5	<	0.8	<	1	≥	1	
GHG RFS2 Eligibility	ENV-AIR-GHG-L05	≥	0.6	>	0.5	>	0.2	>	0	≤	0	
Carbon Sequestration or	ENV-AIR-GHG-M06	≤	0.4	<	0.5	<	0.8	<	1	≥	1	

Figure C-5. Processing and Analysis Worksheet for Energy Diversity Indicator

Microsoft Excel - DLA_Energy_Sust_Assessment_Draft_120612.xlsx									
	A	B	C	D	E	F	G	H	I
1	Pathway Hazard, Consequence, and Mitigation Analysis								
2	Energy Diversity								
3									
4	Pillar	Criteria	Indicator						
5	Operational	Energy Security	Energy Diversity						
6									
7									
8	Indicator Metric Thresholds								
9									
10		Metric Type	Metric Number	Metric Code	Metric	Measure			R_1
11		Likelihood	Metric 1	OP-ES-DIV-L01	Net Energy Return on Investment	mmBtu Input/mmBtu Jet Fuel Output			
12		Likelihood	Metric 2	OP-ES-DIV-L02	Fossil Depletion	Fossil Btu/Total Btu			
13		Likelihood	Metric 3	OP-ES-DIV-L03	Petroleum Reliance	Petroleum Btu/Total Btu			
14		Likelihood	Metric 4	OP-ES-DIV-L04	Coal Reliance	Coal Btu/Total Btu			
15		Likelihood	Metric 5	OP-ES-DIV-L05	Natural Gas Reliance	NG Btu/Total Btu			
16		Likelihood	Metric 6	OP-ES-DIV-L06	Renewable Quotient	Renewable Btu/Total Btu			
17		Likelihood	Metric 7	OP-ES-DIV-L07	Energy Diversity Index	Index			
18		Consequence			Not Applicable	Not Applicable			
19		Mitigation			Not Applicable	Not Applicable			
20									
21									
22									
23									
24	Pathway Assessment For: Soybean Oil HEFA						Summary Results		
25									
26	Pathway References			Metric Inputs		All Stages			Fe
27	Pathway Name			Data Elements	Unit	Total_Data	Total_UOM		S_1
28									
29	Soybean Oil HEFA			Total Energy	Btu/mmBtu of HEFA	1,902,067.79	Btu/mmBtu of HEFA		
30	Soybean Oil HEFA			Fossil Fuels	Btu/mmBtu of HEFA	361,672.18	Btu/mmBtu of HEFA		
31	Soybean Oil HEFA			Coal	Btu/mmBtu of HEFA	53,670.02	Btu/mmBtu of HEFA		
32	Petroleum-based Jet Fuel (2005)			Coal	Btu/mmBtu Jet	15,494.12	Btu/mmBtu Jet		
33	Petroleum-based Jet Fuel (2005)			Natural Gas	Btu/mmBtu Jet	95,350.19	Btu/mmBtu Jet		
34	Petroleum-based Jet Fuel (2005)			Petroleum	Btu/mmBtu Jet	1,069,277.79	Btu/mmBtu Jet		
35	Petroleum-based Jet Fuel (2005)			Renewable	Btu/mmBtu Jet	3,407.23	Btu/mmBtu Jet		
36									
37									
38									
39									
40									
41									
42	Metric Calculations		SOHEFA						
43	Pathway Name	Metric Type	Metric Number	Metric Code	Metric	Measure	Total_Data	Total_UOM	Metric_Rating
44	Soybean Oil HEFA	Likelihood	Metric 1	SOHEFA-OP-ES-DIV-L01	Net Energy Return on Investment	mmBtu Input/mmBtu Jet Fuel Output	1.90	mmBtu Input/mmBtu	4
45	Soybean Oil HEFA	Likelihood	Metric 2	SOHEFA-OP-ES-DIV-L02	Fossil Depletion	Fossil Btu/Total Btu	0.19	Fossil Btu/Total Btu	1
46	Soybean Oil HEFA	Likelihood	Metric 3	SOHEFA-OP-ES-DIV-L03	Petroleum Reliance	Petroleum Btu/Total Btu	0.04	Petroleum Btu/Total Btu	1
47	Soybean Oil HEFA	Likelihood	Metric 4	SOHEFA-OP-ES-DIV-L04	Coal Reliance	Coal Btu/Total Btu	0.03	Coal Btu/Total Btu	1
48	Soybean Oil HEFA	Likelihood	Metric 5	SOHEFA-OP-ES-DIV-L05	Natural Gas Reliance	NG Btu/Total Btu	0.12	NG Btu/Total Btu	1
49	Soybean Oil HEFA	Likelihood	Metric 6	SOHEFA-OP-ES-DIV-L06	Renewable Quotient	Renewable Btu/Total Btu	0.81	Renewable Btu/Total Btu	1
50	Soybean Oil HEFA	Consequence	Metric 7	SOHEFA-OP-ES-DIV-L07	Energy Diversity Index	Index	0.10	Index	5
51	Soybean Oil HEFA	Consequence			Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Figure C-6. Detailed Results Worksheet for Soybean HEFA Example

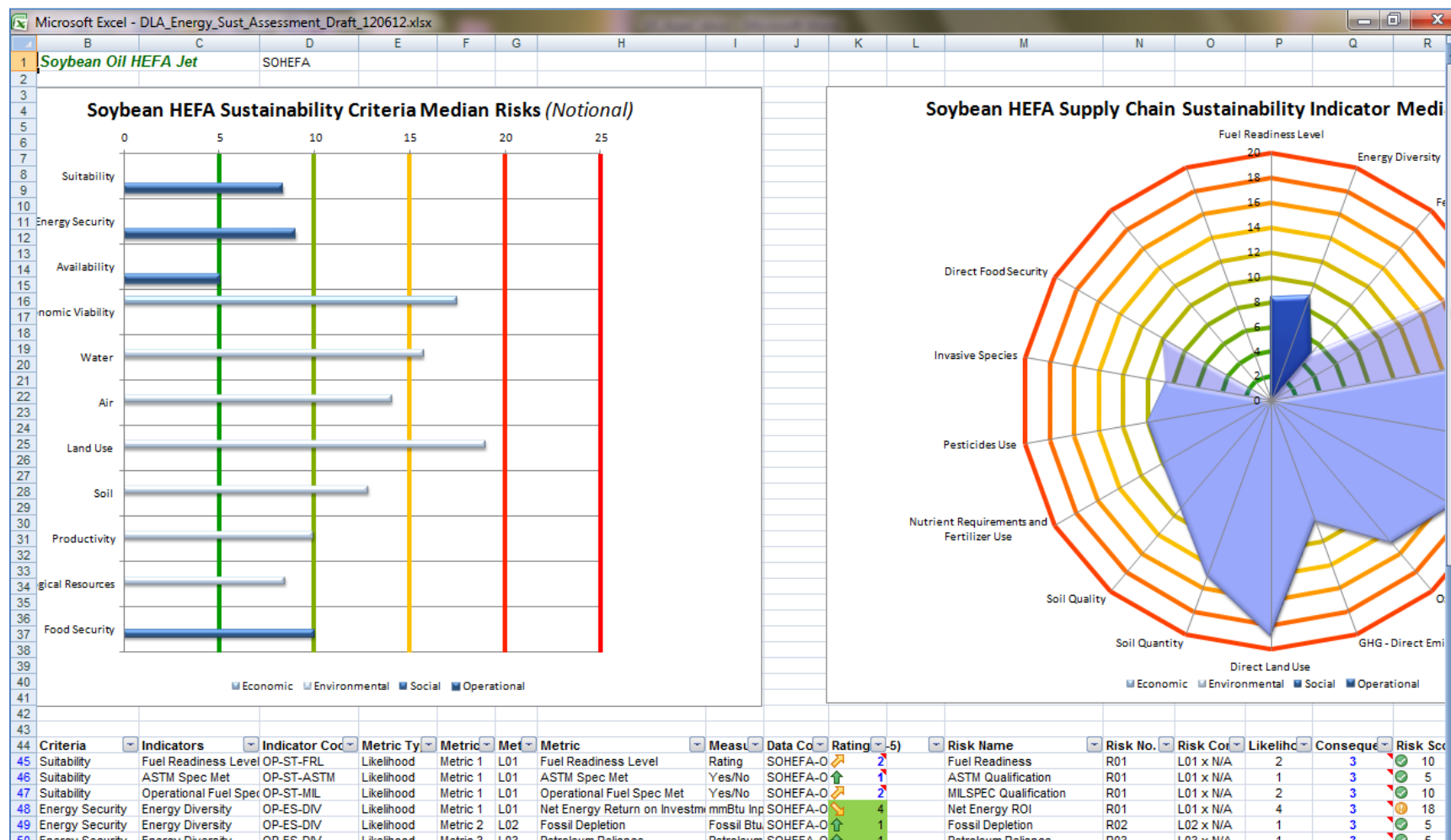


Figure C-8. Comparative Risk Results Worksheet

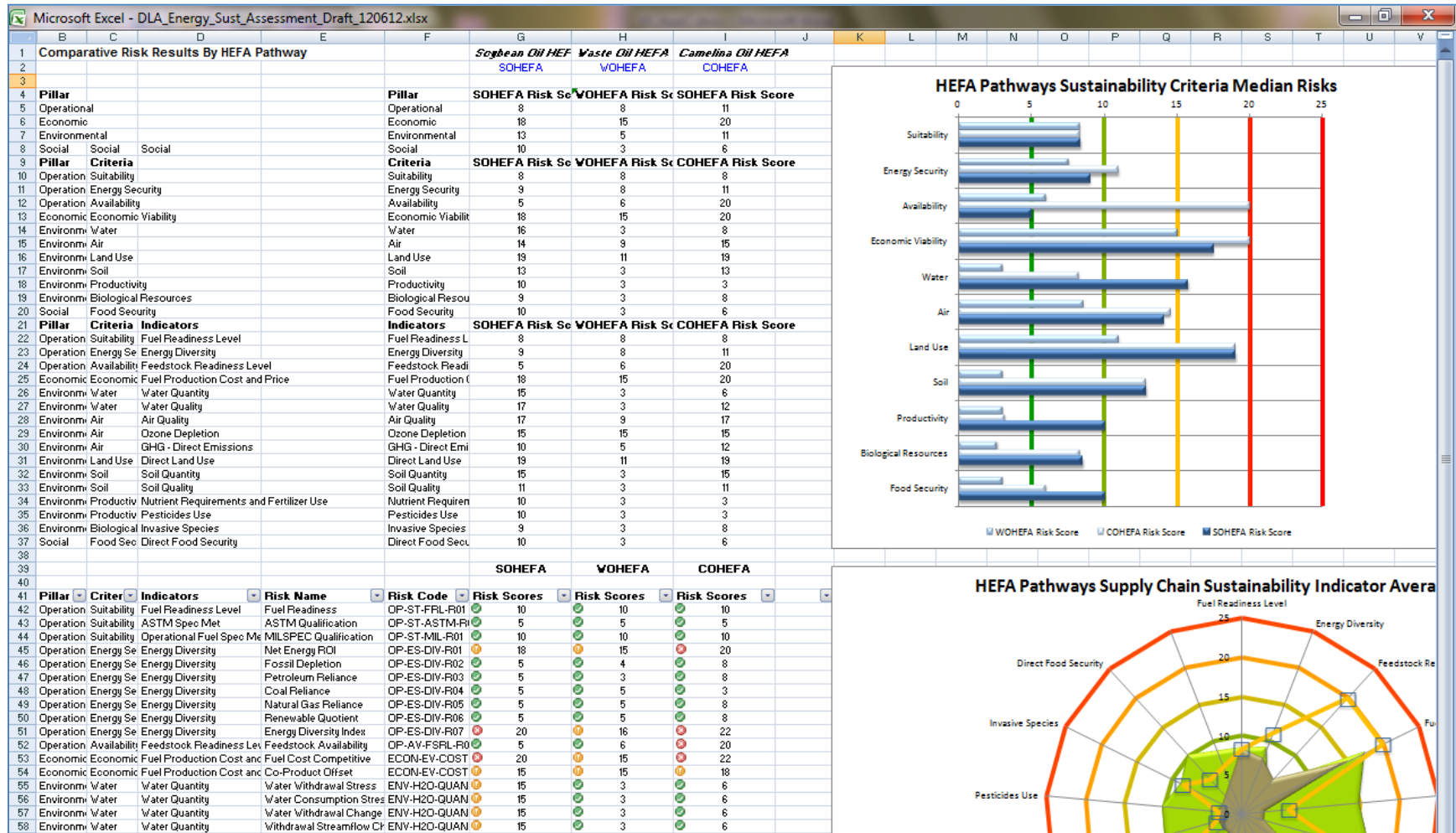
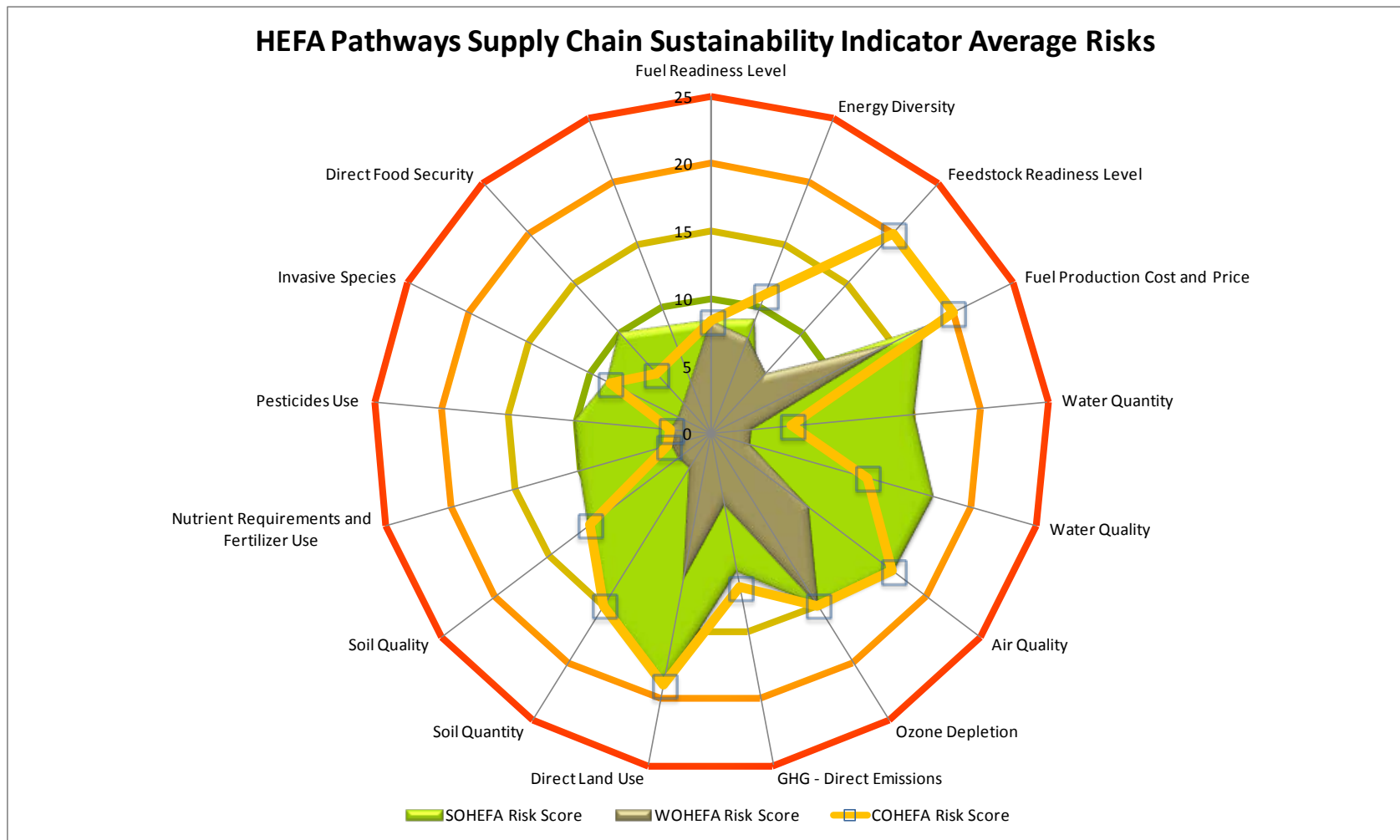


Figure C-9. Preliminary Risk Results for Soybean, Waste, and Camelina Oil HEFA



Appendix D

Definitions

Alternative fuels are transportation or mobility fuels not composed of or derived from liquid petroleum, including synthetic and renewable fuels.

Synthetic fuels are liquid hydrocarbon fuels produced from coal, natural gas, or biomass.

Renewable fuels are transportation or mobility fuels, used alone or blended with petroleum-based fuel, and wholly derived from “renewable biomass” or its decay products.

Biofuels are fuels produced from biomass material or biogas source.

Operational Biofuels are synthetic diesel or jet fuels produced wholly or partially from biomass material or biogas source that drop-in qualified or certified for use (currently only up to 50/50 blend) in tactical system and weapons platforms.

Architecture refers to the functional components needed to frame the sustainability analysis, identify biofuel pathway of interest, process for performing an assessment, and outputs that inform insights, recommendations, and decisions.

Framework refers to a basic conceptual structure that can be used to consistently assess the individual or relative sustainability of a given biofuel.

Pillars refer to the foundational principles and groupings within a given sustainability framework that may include economic, operational, environmental, and social aspects. Each pillar is composed of one or more criteria.

Criteria refer to secondary categories within a specific pillar that describe resources, media, capacities, or other attributes across the biofuel life cycle. Criteria are composed of one or more indicators.

Indicators refer to specific gauges of performance, impact, and supply chain risk for a given criterion. One or more quantitatively or qualitatively defined metrics may be used to assign value to indicators.

Metrics refer to the measurable characteristic, impact, or risk mitigation attributes of a particular indicator.

Likelihood refers to the probability of supply chain hazard reflecting feedstock and conversion pathway characteristics.

Consequence refers to the severity of supply chain impacts as a result of regional- or site-specific conditions or relative sensitivities.

Mitigation refers to plans, technologies, or practices to manage or reduce the raw supply chain risk.

Appendix E

Abbreviations

A2AD	Anti-Access/Area Denial
A4A	Airlines for America
ABSA	American Biological Safety Association
ACI-NA	Airports Council International - North America
AEPI	Army Environmental Policy Institute
AESIS	<i>Army Energy Security Implementation Strategy</i>
AFCD	Alternative Fuel Certification Division
AFRE	alternative fuels and renewable energy solutions
AFRL	Air Force Research Laboratory
AGWA	Automated Geospatial Watershed Assessment
AIA	Aerospace Industries Association
ANL	Argonne National Laboratory
AOI	area of interest
APTI	Air Pollution Training Institute
ARO	Army Research Office
ARPA-E	Advanced Research Project Agency – Energy
ARS	Agricultural Research Service
ASA(IE&E)	Army for Installations, Energy and Environment
ASCP	Army Sustainability Campaign Plan
ASD(OEPP)	Assistant Secretary of Defense for Operational Energy Plans and Programs
ASR	Army Sustainability Report
ATA	Air Transportation Association
ATJ	alcohol-to-jet
BAA	Broad Agency Announcement
BCAP	Biomass Crop Assistance Program
BFI	Baseflow Index
bio-SPK	bio-derived synthetic paraffinic kerosene

BLM	Bureau of Land Management
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BRC	Bioenergy Research Center
BRD	Biomass Research and Development
BRDA	Biomass Research and Development Act
BRDI	Biomass Research and Development Initiative
C4I	command, control, communications, computers, and intelligence
CAA	Clean Air Act
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAPEX	Capital Expenditures
CARD	Center for Agriculture and Rural Development
CAST	Council for Agricultural Science and Technology
CBA	Capabilities Based Assessment
CBES	Center for Bioenergy Sustainability
CBET	Chemical, Bioengineering, Environmental and Transport Systems Division
CCC	Commodity Credit Corporation
CCLUB	Carbon Calculator for Land Use Change from Biofuels Production
CEAP	Conservation Effects Assessment Project
CEQ	Council on Environmental Quality
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CO	carbon monoxide
CO ₂	carbon dioxide
COD	Chemical Oxygen Demand
CONUS	contiguous United States
CRJ	catalytic renewable jet
CRM	continuous risk management
CRP	Conservation Reserve Program
CSBP	Council on Sustainable Biomass Production

CSIS	Center for Strategic and International Studies
CTA	Conservation Technical Assistance
CUE	Critical Use Exemption
CWA	Clean Water Act
DARPA	Defense Advanced Research Projects Agency
DASD(MIBP)	Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy
DDGS	dry distillers' grains with solubles
DLA	Defense Logistics Agency
DLUC	direct land use change
DoD	Department of Defense
DOE	Department of Energy
DOEB	Defense Operational Energy Board
DOEPP	Director of Operational Energy Plans and Programs
DORRA	DLA Office of Operations Research and Resource Analysis
DOT	Department of Transportation
DPA	Defense Production Act
DUSD(I&E)	Deputy Under Secretary of Defense for Installations and Environment
DWCF	Defense Working Capital Fund
EC	European Commission
E ² O	Expeditionary Energy Office
E2W2	Expeditionary Energy, Water and Waste
EA	Environmental Assessment
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act

EQIP	Environmental Quality Incentives Program
ERS	Economic Research Service
ESA	Endangered Species Act
ESG	Executive Steering Group
ESOH	Environment, safety, and occupational health
ETDEWEB	Energy Technology Data Exchange's World Energy Base
ETS	Emissions Trading System
EU	European Union
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Farm and Agricultural Policy Research Institute
FAR	Federal Acquisition Regulation
FAS	Foreign Agricultural Service
FASOM	Forestry and Agriculture Sector Optimization Model
FCEA	Food Conservation and Energy Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOA	Funding Opportunity Announcement
FONSI	Findings of No Significant Impact
FS	Forest Service
FSA	Farm Service Agency
FSC	Forest Stewardship Council
FSRL	feedstock readiness level tool
F-T	Fischer-Tropsch
FUDS	Formerly Used Defense Sites
GBEP	Global Bioenergy Partnership
GDG	Geospatial Data Gateway
GHG	greenhouse gases
GMO	genetically modified organism
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model
GSA	General Services Administration
GSPEL	Ground Vehicle Power and Energy Laboratory
GWP	global-warming potential

HAP	hazardous air pollutant
HBFC	hydrobromofluorocarbon
HCFC	hydrochlorofluorocarbon
HEFA	hydroprocessed esters and fatty acids
HEL	highly erodible lands
HRF	hydrotreated renewable fuel
IARB	Integrated Acquisition Review Board
IAWG	Interagency Working Group
IBPE	Integrated Biofuels Production Enterprise
IGCE	independent government cost estimate
IGSA	Internal Government Sustainability Assessment
ILUC	Indirect Land Use
IPaC	Information, Planning, and Conservation
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPT	Integrated Product Team
IRS	Internal Revenue Service
ISO	International Organization for Standardization
JLUS	Joint Land Use Study
JP	jet propellant
KDF	Knowledge Discovery Framework
LCA	life-cycle analysis
LCI	life-cycle inventory
LHV	low heat value
MACT	Maximum Achievable Control Technology
MIT	Massachusetts Institute of Technology
MJ	megajoule
MMPA	Marine Mammal Protection Act
MOU	memorandum of understanding
MSW	municipal solid waste
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration

NASS	National Agricultural Statistics Service
NAVAIR	Naval Air Command
NAVSUP	Naval Supply Systems Command
NBAP	National Biofuels Action Plan
NCEA	National Center for Environmental Assessment
NCER	National Center for Environmental Research
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NETL	National Energy Technology Laboratory
NextGen	Next Generation Air Transportation System
NGO	non-governmental organization
NIFA	National Institute of Food and Agriculture
NOLSC	Naval Operational Logistics Support center
NPDES	National Pollutant Discharge Elimination System
NPP	net primary production
NRCS	Natural Resources Conservation Service
NRDC	Natural Resources Defense Council
NRE	Natural Resources and Environment
NREL	National Renewable Energy Laboratory
NRI	National Resources Inventory
NRML	National Risk Management Research Laboratory
NSF	National Science Foundation
NTV	non-tactical vehicle
NWF	National Wildlife Federation
NWIS	National Water Information System
OASD(OEPP)	Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs
OBP	Office of Biomass Program
ODP	ozone depletion potential
ODS	ozone depleting substances
OEM	original equipment manufacturer
OMB	Office of Management and Budget

OPA	Oil Pollution Act
ORD	Office of Research and Development
OPEX	Operating Expenditures
ORNL	Oak Ridge National Laboratory
OSD	Office of the Secretary of Defense
OSD(AT&L)	Office of the Under Secretary of Defense (Acquisition, Logistics, and Technology)
OSHA	Occupational Safety and Health Administration
OSTP	Office of Science and Technology Policy
OTAQ	Office of Transportation and Air Quality
P2	pollution prevention
PAD	Petroleum Administration for Defense
P.L.	Public Law
PM	particulate matter
PNNL	Pacific Northwest National Laboratory
POL	petroleum, oil, and lubricants
PTC	producer tax credit
PWS	performance work statement
QDR	Quadrennial Defense Review
QT	Quality Technical
RCA	Resources Conservation Act
RCB-X	Riverine Command Boat
RCRA	Resource Conservation and Recovery Act
R&D	research and development
RDT&E	research, development, testing, evaluation
REAP	Rural Energy for America Program
REE	Research, Education and Economics
RFI	Request for Information
RFS	Renewable Fuel Standard
RIMPAC	Rim of the Pacific
RIN	Renewable Identification Number
RRAC	Regulatory Risk Analysis and Communication
RSB	Roundtable on Sustainable Biofuels

RUSLE	Revised Universal Soil Loss Equation
SBIR	Small Business Innovation Research
SCOR	Supply Chain Operations Reference
SDWA	Safe Drinking Water Act
SIP	State Implementation Plan
SIRRA	Sustainable Installations Regional Resource Assessment
SMART	specific, measurable, actionable, relevant, and timely
SME	subject matter expert
SNAP	Significant New Alternatives Policy
SOC	soil organic carbon
SOW	statement of work
SPK	synthetic paraffinic kerosene
SSC	Senior Sustainability Council
SSO	senior sustainability officer
SSPP	strategic sustainability performance plan
STTR	Small Business Technology Transfer
SWPPP	Stormwater Pollution Prevention Plan
TAC	Technical Advisory Committee
TARDEC	Tank Automotive Research, Development and Engineering Center
TARWR	total actual renewable water resources
TAWW	total annual water withdrawals
T&E	threatened and endangered
TMDL	Total Maximum Daily Load
TSCA	Toxic Substance Control Act
TSS	total suspended solids
USAF	United States Air Force
U.S.C.	United States Code
USDA	United States Department of Agriculture
USD, AT&L	Undersecretary of Defense for Acquisition, Technology and Logistics
USFS	US Forest Service
USG	United States Government

USGS	US Geological Survey
USLE	Universal Soil Loss Equation
USMC	United States Marine Corps
VEETC	Volumetric Ethanol Excise Tax Credit
VOC	volatile organic compound
WATERSHEDSS	Water, Soil, and Hydro-Environmental Decision Support System
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WRA	Weed Risk Assessment
WRI	World Resources Institute
WS-5	Warfighter Support 5
WSS	Web Soil Survey

